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Foundation Investigation for the
Proposed Plant Site and Access Road
Federal Lease Tract C-b
Rio Blanco County, Colorado



Golder Associates

CONSULTING MINING AND GEOTECHNICAL ENGINEERS

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FOUNDATION INVESTIGATION FOR THE
PROPOSED PLANT SITE AND ACCESS ROAD
FEDERAL LEASE TRACT C-b
RIO BLANCO COUNTY, COLORADO

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CONSULTING MINING AND GEOTECHNICAL ENGINEERS

December 18, 1975

C-b Shale Oil Project
Shell Oil Company, Operator
1700 Broadway
Denver, Colorado 80202

ATTENTION: Mr. C. T. Allen, Manager
Surface Facilities

RE: PROJECT REPORT
C-b FOUNDATION INVESTIGATION

Gentlemen:

We are pleased to submit our report covering the Foundation Investigation for the Proposed Plant Site and Access Road, including the Piceance Creek Crossing, at the Federal Oil Shale Tract C-b, Rio Blanco County, Colorado.

The report contains the results of field exploration and mapping programs, and laboratory analyses on representative samples of materials to be used in engineered embankments. Geotechnical design criteria and construction considerations are presented for the plant site foundations, coarse ore storage and handling facilities, and the access road to the Piceance Creek highway. No discussion of the proposed dam location has been included in this report, pending receipt of authorization to proceed with the investigation.

Yours very truly,
GOLDER ASSOCIATES, INC.

A. Allen Gass, Principal
Project Manager

William Heley
Project Engineer

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CONTENTS

	<u>PAGE</u>
1.0 INTRODUCTION	1
2.0 SUMMARY OF PREVIOUS WORK	2
3.0 PROCEDURE	3
4.0 SURFACE FACILITIES	
4.1 Subsurface Conditions	6
4.2 Geotechnical Design Criteria	7
4.3 Construction Considerations	12
5.0 ACCESS ROAD	
5.1 Subsurface Conditions	13
5.2 Geotechnical Design Criteria	13
5.3 Construction Considerations	15
6.0 PICEANCE CREEK CROSSING	
6.1 Subsurface Conditions	17
6.2 Geotechnical Design Criteria	17
6.3 Construction Considerations	18
GLOSSARY	20
BIBLIOGRAPHY	73
APPENDIX A	74

LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
I	Typical Structural Loads - Plant Site	8

<u>FIGURE</u>		
1	Key Plans	21
2	Test Site Location Map C-b Plant Site Foundation Investigation	22
3	Summary of Vertical Sections in Test Pits	23
4	Refusal Elevation and Depth Versus Surface Elevation	24
5	Fracture Data: Test Pits 1 - 15	25
6	Fracture Data: Test Pit 16	26
7	Unconfined Compressive Strengths from Test Pits	27
8	Summary of Previous Data on Unconfined Compressive Strengths	28
9	Diagrammatic Cross Section and Stratigraphy of Test Pit 16, Looking North	29
10	Stacker Bench and Reclaim Trench	30
11	Typical Test Pit Photographs	31
12	Typical Test Pit Photographs	32
13	Typical Test Pit Photographs	33
14	Geologic Map and Section along Stearns-Roger Revised Road Alignment C-b Foundation Investigation	34
15	Laboratory Compaction Test Results	35
16	Laboratory Compaction Test Results	36
17	Laboratory Compaction Test Results	37
18	Compaction and CBR Test Results	38
19	Borehole Plan and Stratigraphy	39

<u>FIGURE</u>		<u>PAGE</u>
20	Grain Size Distribution	40
21	Grain Size Distribution	41
22	Grain Size Distribution	42
	Records of Test Pits	43
	Records of Boreholes	63

1.0 INTRODUCTION

This report presents the results of an investigation of foundation conditions for facilities proposed for Federal Oil Shale Lease Tract C-b in Rio Blanco County, Colorado. The work was carried out in accordance with our proposal to Shell Oil Company dated September 8, 1975, and accepted by Purchase Order No. VMD-10077 C.M.S. dated September 11, 1975.

The proposed work was divided into two phases. Phase I involved investigation for the process plant, mine surface facilities, coarse ore handling and storage, and access and service roads including the Piceance Creek Crossing. Phase II included investigations for a diversion dam upstream from the proposed spent shale disposal area in Sorghum Gulch and a retention dam downstream from the disposal area. Subsequent to acceptance of the proposal it was decided that the diversion dam would not be required and that investigation for the retention dam should be postponed pending further definition of its required function. Therefore, this report covers only the work defined for Phase I in our proposal.

The purpose of the Phase I investigation was to carry out the work necessary to define subsurface conditions for the proposed facilities after making maximum utilization of all pertinent work carried out previously on both the C-b Tract and the related Colony Development property to the South. Upon completion of the investigatory work, geotechnical criteria were to be established for the design and construction of the proposed facilities. The location of the areas investigated are shown in Figure 1.

2.0 SUMMARY OF PREVIOUS WORK

Prior to the formulation of the test program, previous studies were reviewed to determine the type and quantity of data already available on the engineering characteristics of the soils and bedrock. Studies referred to directly or indirectly in this report have been listed in the bibliography.

Two types of background studies were performed prior to this investigation. The first type was geologic mapping and surficial geology studies which have been made throughout the Piceance Basin. The most useful data was obtained from the Colony Development property at Parachute Creek, Colorado and from the C-b Tract vicinity at Piceance Creek. Surface exposures at both sites include the interbedded sandstones and siltstones of the Uinta Formation which are characteristic of the entire sequence.

The second type of study dealt with the engineering properties of the formation materials both in place and as an engineered fill. Prior to this study, however, the bulk of available information was obtained at the Colony Development Operation proposed plant site investigations from 1972 to 1974.

For the purposes of this study, the most applicable information was derived from the surficial geology study of Amuedo and Ivey (2)(11)* and the geotechnical studies involving tests of rippability of the rock and embankment compaction (5) (8). Additional data on characteristics and strength of the rock mass was available from the recently completed Mineability Study by Golder Associates, Inc. for Atlantic Richfield Company (14).

* Underlined numbers in parentheses refer to the bibliography.

3.0 PROCEDURE

The field work was carried out during the months of October and November, 1975. The plant site area was examined for foundation characteristics and the access road was examined for slope stability characteristics, compacted fill performance, and subgrade support capability, particularly in the area of the stream crossing in the Piceance Valley. The work was carried out, generally, in accordance with a set of directives issued by Mr. A. T. Ireson, Manager, Leasehold Development for Shell Oil Company entitled "Regulations for On-Site Activities" and "Items of Archaeological, Historic or Scientific Interest: Guidelines for Field Operations". Specific activities were reviewed on site with Ms. Joan Gibbs, Environmental Field Coordinator for the C-b Shale Oil Project.

Figure 2 shows the specific area defined by Shell Oil Company as the plant site. Also shown are locations of Environmental Baseline Study Plots where surface disturbance could not be tolerated. Initially, 15 locations were selected which represented the approximate areas where major structures or foundations were proposed in the Preliminary Overall Site Plans by C. F. Braun & Co. The locations of specific structures could be subject to revision with final design, so the test pit program was also designed to give a representative areal coverage and a stratigraphic variation with elevation across the plant area. The location and orientation of these pits are also shown on Figure 2.

Following completion of 15 L-shaped pits, additional information was received from Stearns-Roger Inc., which refined certain locations previously estimated from sketches. The coarse ore storage and reclaim facility was outside the initial test pit area. Because this facility constitutes a potential stability problem due to the magnitude of loading and depths of excavation proposed, an additional test pit was excavated across the alignments of the coarse ore stacker and the reclaim tunnel to intersect beddings and establish the rock profile. This trench also provided a correlation of bedding not possible from the other smaller test pits.

The excavated pits varied with depth to refusal depending on rock type and extent of weathering. Geologic profiles were measured across the bedding exposed in the pit walls. Fracture orientations, fracture intensities, stains, infillings and inclusions were identified. The test trench was also examined by a geologist and five profiles were mapped along its length. The detailed descriptions of the geology prepared from these pits are included in Appendix A of this report.

After the test pits had been logged, Mr. Addison Meyers of Amuedo and Ivey was requested to inspect the test pits and compare exposed conditions with conclusions contained in the report on surface Geologic Mapping Program prepared by Amuedo and Ivey for the C-b Tract.

The procedure followed for investigation of the proposed access road consisted of a detailed field mapping of all geologic features exposed for a distance of about 200 ft. on each side along the proposed route down the Piceance Creek Valley. No test pits were excavated, but samples considered to be representative of material to be excavated along the route were taken from the following locations:

1. (106-1) Soil/weathered sandstone mixture from disturbed area on ridgetop road alignment at drill pad SG-2.
2. (106-2) Sandstone refusal layer in floor of Test Pit 16.
3. (106-4) Alluvium from East bank of stream channel near PI#3 on road alignment.

The Piceance Creek Valley and the crossing of Piceance Creek were investigated by four borings, two immediately adjacent to the creek, and two in the areas intermediate between the creek and the valley walls. The holes were put down using a truck-mounted auger rig supplied by Custom Auger Drilling Service, Inc. of Denver. Standard drive samples were taken at five foot intervals of depth.

A limited program of laboratory testing was carried out to check the properties of materials which had not been sufficiently defined in previous work. The unconfined compressive strength of the upper rock mass was checked by cutting rectangular specimens from representative samples from the test pits. Finally, index tests were run on samples from one of the borings at the Piceance Creek crossing to confirm visual classifications.

Locations were established in the field by taping or pacing from prominent topographical or man-made features. Elevations of the test pits were established by leveling from Reference Point No. 22 with a given elevation of 6899.06 ft. Elevations of the borings at Piceance Creek were estimated from the countour plans. All elevations employed in the report are referred to Mean Sea Level Datum.

4.0 SURFACE FACILITIES

4.1 Subsurface Conditions

Test pits were excavated in the areas of critical interest as defined in the Detailed Development Plan. Other pits were located in contiguous sites to provide areal coverage. Figure 3 shows the vertical section exposed by the pits; a nearly continuous exposure of approximately 170 ft. resulted from the pits. The test pit records follow the figures in this report.

In nearly all cases, excavation extended to effective refusal. The depth to refusal was not widely different across the test area, although the materials excavated varied from soil to weathered sandstone and siltstone. Figure 4 represents the depth to refusal versus surface elevation. An average depth of 8⁺ feet was required to reach refusal. In some instances, due to locally hard or unweathered zones, refusal depth ranged upward to two feet or less.

Rock characteristics measured in the excavations have been described in detail in the geologic summaries of Appendix A. The test pit records follow the figures at the end of this report. The rock exposed was fractured to varying degrees, from intensely fractured near the surface to progressively less fractured with depth. Schmidt-Lambert Equal Area Projections were prepared for fracture orientations exposed in the pits and are presented as Figures 5 and 6. A predominant orientation of approximately N65°W and an average dip of 65°N and S was measured for the most persistent fractures. This near-surface expression of fracture orientation was corroborated by the results of fracture studies performed on core samples extracted from four inclined holes bored on the C-b Tract during the Mineability Study in 1975 (14). A summary of those results is also shown on Figures 5 and 6.

In addition to fracture measurements, strength testing was performed on specimens cut from rock samples obtained in the test pits. Unconfined compressive strengths determined from crushing tests are shown in Figure 7. An average strength of 1500 psi was obtained in these tests which is considered to be representative of the intact rock. Anomalous results of

higher strength siltstone layers were not included in this average. Results of unconfined compression test on samples from deeper in the formation are shown to be consistently greater than 1500 psi in Figure 8. (14)

The test pits exposed interbedding and lateral variation in the formation across relatively short distances. Test Pit 16, an extended trench down the slope, crossed the projected location for the coarse ore stockpile and reclaim operation. A profile was prepared from measurements in this trench and is included as Figure 9. This profile illustrates the type of materials anticipated in the stacker bench and reclaim trench excavation, and it also shows the variation in refusal depth encountered with different rock types. The proposed stacker bench and reclaim trench is shown schematically as Figure 10. The schematic drawing was included with the request for proposal for this study.

Figures 11 through 13 are photographs considered most representative of the rock exposures made in the test pits. Explanatory notes on the figures define the locations of the photos and the significant features illustrated. A complete set of photographs of the test pits is on file, but they were not reproduced in this report.

4.2 Geotechnical Design Criteria

Anticipated loading of foundations have been taken from the report entitled "Geotechnical Studies, Proposed Plant Site, Colony Shale Oil Plant" (5). These loadings are expressed as total weights. No definition of the numbers of columns proposed to support these loads was given.

The proposed loadings are summarized in Table I on the following page.

TABLE I TYPICAL STRUCTURAL LOADS - PLANT SITE

STRUCTURE	OVERALL SIZE	FOUNDATION LOADING
Pyrolysis structure	130' x 415'	Column Loads: 290 to 950 tons
Fractionator	31' Dia	600 Tons
Coke Drums	36' x 66'	6400 Tons
Fine Ore Silo	125' Dia	25,400 Tons
Stacker	30' x 30'	500 tons
Reclaim Tunnel	15' x 900'+	365 Tons/Lin Ft.*
Storage Tanks	190' Dia	1.75 Tons/Sq.Ft.

*Assumes ore at 85 pcf stacked to 190' height

The heavy plant loads should be founded on the relatively sound rock which is present generally at a depth of about 8 ft. below ground surface. In part, this will ensure stability of the plant components and will also permit use of the maximum practicable bearing capacity, thus minimizing the volume of concrete required for foundations. The latter is of economic importance because of the lack of suitable concrete aggregate on or near the site. Therefore, using an 8 ft. minimum cut as a guideline, the grading of the site may be planned so that all bearing loads can be readily founded in rock, using the fill in other areas of lighter and less sensitive loadings. It should be recognized, of course, that the figure of 8 ft. is an average and some variation should be expected in the field. In the area presently proposed for the plant along the top of the ridge such variations are not likely to be very large, probably not more than a few feet at any location.

The results of the investigation indicate that down to a depth of 8 ft. or more the unconfined compressive strength of the rock mass is of the order of 1500 psi (approximately 100 tons/sq. ft.). Furthermore, at this depth the fracture density is decreasing markedly and the fractures are tight. It is considered, therefore, that an allowable bearing pressure of 50 tons/sq. ft. may be employed with a reasonable margin of safety against failure.

Settlement of individual footings designed for this load intensity would be made up of two components, namely the elastic compression of the rock mass and the closing of the fractures within the loaded zone. It is considered that elastic settlements would be negligible, even allowing for a ten-fold reduction in the modulus of elasticity of about 1×10^6 psi (5) previously reported for both the Colony Development property and the C-b Tract. The computed settlement would be a small fraction of an inch. Similarly, the fractures are relatively tight below a depth of about 8 ft. and further closure should result in only minor settlement. For design purposes it is recommended that a maximum settlement of an individual footing of one inch be assumed with a maximum differential settlement between elements of about 3/4 inch.

Lightly loaded and relatively flexible structures such as office buildings, warehouses, maintenance buildings and change houses may be founded on fill provided it is placed in accordance with discussions given below, and provided the thickness of fill is at least three feet and is constant or uniformly varying. No structures should be placed partially on fill and partially on rock or on fill which varies abruptly in thickness. An allowable bearing capacity of five tons/sq. ft. may be employed for foundations in fill. Storage tanks, which will exert a uniform maximum loading intensity of about 1.75 tons/sq.ft. may also be founded on fill provided the above conditions are satisfied.

It is recommended that a minimum of three ft. of frost cover be provided above the base of all exterior footings. Although the normal depth of frost penetration may be greater, it is considered that in view of the general absence of free groundwater a cover of three feet will be sufficient to maintain the integrity of the subgrade.

Structural foundation walls which retain soil should be designed for the "at-rest" condition in order to ensure minimal lateral movement. It is recommended that an equivalent fluid pressure of 55 lb/sq.ft. be employed to satisfy this condition. Foundation drains should be provided for these walls to ensure that there is no build up of water pressure on the walls, especially during the spring thaw period. Normal free-standing retaining walls, if required, may be designed for active earth pressure using an equivalent fluid pressure of 40 lb/sq.in. and drains or seep-holes should be

provided at regular intervals. Backfill for all retaining walls should be derived from the excavated sandstones.

Chemical analyses indicate the presence of sulfates up to 650 ppm (17) in the surface soils. This level will possibly vary with depth, but the potential for sulfate deterioration of concrete is considered negligible. Type I cement would be adequate for concrete subjected only to normal soil sulfate levels. If additional sulfates will be introduced to the soils through processing, spillage, or other means, the cumulative effect may warrant the use of Type II or Type V cement.

A bench will be required to support a rail mounted stacker and conveyor which will discharge to the northwest into a trench lying parallel to the bench. The dimensions of the stacker bench, as shown in Figure 10, will be approximately 80 feet in width and 860 feet in length. The reclaiming trench will be of trapezoidal cross section with a top width of 300^{+} feet, a bottom width of 110^{+} feet and a depth of 125 feet. A stockpile will be constructed of oil shale crushed to a nominal maximum size by a primary crusher. This stockpile may contain up to 5,000,000 tons and be constructed up to 190 feet in height, although the normal stockpile will contain about 500,000 tons and be contained by the trench.

The coarse ore storage and reclaim area should be constructed entirely in cut to a minimum depth of eight feet. Cut slopes should be limited to a net 1:1 maximum. To facilitate drilling and blasting and also provide a larger working area along the edge of the bench, a series of 60° cuts with benches could be built instead of a continuous 45° slope. This recommendation is expressed for consideration by the designer and is not intended as a design specification.

Regional fractures at $N65^{\circ}W$ will intersect the cut slope at approximately right angles and should not pose a stability problem. However, the slopes should be inspected during construction to identify any localized problems which may arise so remedial measures can be taken to correct the instability.

The reclaim tunnel will probably be excavated as an open trench in the bottom of the primary coarse ore trench and will be approximately 25 feet below that grade. Once constructed, the tunnel will be required to support the weight of the maximum fill height, but will be founded in

sound rock, and no bearing capacity problems will exist. At a loading of 365 tons/lin. ft., the tunnel will exert approximately 25 tons/sq. ft. on the rock.

The current alignment for the coarse ore storage and reclaiming system is on a bearing of N20°E. This system hinges from a transfer house positioned at the approximate coordinates N 181, 395, E 1, 237, 790; the stacker bench elevation has been established as 6850 ft. mean sea level. If the present alignment and bench elevation are followed, the last 150 ft. of the stacker bench will be situated on fill or in cut of insufficient depth. A revised alignment of N27°E from the same hinge point would provide a rock surface with sufficient bearing capacity for the stacker equipment.

The coarse ore stockpile will extend across the full width of the East Fork of Cottonwood Gulch as presently envisioned. Although no plant site drainage plan was provided to Golder, we assume some watershed will lie above the stockpile. Drainage which would naturally flow past the storage site should be diverted into the West Fork of Cottonwood Gulch. This could be accomplished by a small diversion structure and an open ditch along a contour to the other drainage.

Prior to placement of the stockpile, the entire area to be covered should be stripped of the colluvium which covers the bedrock, although weathered rock need not be removed. Due to the height of the stockpile, this unconsolidated material could cause instability at the toe of the slope if not removed. The material stripped from the coarse ore area could be stockpiled and used for landscaping the completed plant area, which will otherwise consist of a significant acreage of exposed bedrock, or could be used as a soil cover on the final slopes of the spent shale disposal embankment.

Materials excavated from the coarse ore reclaim area can also be used to advantage in several ways. Following stripping, these materials can be used to regrade the area under the proposed stockpile to prepare a favorable grade for reclaiming the portion beyond the live storage trench. These materials should also provide a good source for backfill materials around foundations and retaining walls. Depending upon the actual construction schedule, the trench may prove to be the best source for base course materials on the access road and paved parking lots, etc. This subject will be discussed in more detail under the Access Road heading.

4.3 Construction Considerations

Footing excavations should not be made any sooner than is necessary to allow an efficient construction of the foundations. Prolonged exposure to the elements may deteriorate the surfaces of the rock, especially during freeze-thaw cycles. A recommended maximum exposure of one month should be followed. Surfaces exposed for longer periods may require removal of deteriorated material prior to concrete placement.

Compaction control will be essential to develop the specified bearing capacity in fill areas. Proper compaction will be dependent upon the degree to which rock sizes are broken down and voids between rocks are filled. Moisture control will also be necessary but will not require precise tolerances due to the granular nature of the fill. Lift thickness will be limited by the capability of the placement/compaction equipment to crush the rock and attain densification. Breaking down of the sandstones and siltstones will obviously be accomplished easier by heavy equipment. The number of passes required will be determined by building a test section on site with the applicable compactors. Density should be specified as a percent of optimum density determined by standard moisture-density test T 180-57 (AASHTO). Structural fills should be compacted to a minimum density of 95 percent of optimum. Other fills such as parking areas, storage yards, etc. should be compacted to a minimum density of 90 percent of optimum.

Prior to fill placement, areas to be covered should be stripped of surface vegetation and organic material removed. Holes, pits, and other depressions within the fill area should be filled and compacted prior to the placement of fill. Side slopes of the fills should not exceed 1.5 horizontal to 1 vertical.

The material excavated or exposed in the test pits was considered rippable. However, this does not preclude the existence of zones of hard materials which cannot be ripped economically. An allowance should be made for drilling and blasting up to 15 percent of the materials encountered to a depth of 25 feet. Beyond that depth, some ripping may be possible, but it is likely that drilling and blasting may be required for most of the excavation.

5.0 ACCESS ROAD

5.1 Subsurface Conditions

The access road alignment and profile are shown in Figure 14. Beginning near the plant site at station 100 + 00, the road travels northward along the ridge line for approximately one mile before steepening its descent through a gulch and into the Piceance Valley. The road alignment was examined superficially, but no excavations were made specifically for the purpose of exposing the subsurface.

The ridge top portion of the road will lie on weathered sandstones and siltstones much as the existing roads do. This material will be exposed in cut and will be used as fill to establish the road grade. The portion of the road which cuts down through the stratigraphic column in the gulch area will intersect more massive sandstones and will require deeper sidehill cuts to maintain alignment and grade through the narrow gulch. As the gulch widens toward its mouth, the valley floor becomes an alluvial fill of increasing thickness to a maximum of about 70 ft. near the confluence with Piceance Creek.

Each of the type of materials comprising the road foundation has been sampled and tested, e.g. soil and weathered sandstone (S106-1), fresh sandstone (S106-2), and streambed alluvium (S106-4). Figures 15 through 17 show the moisture-density relationships obtained in laboratory compaction tests on these samples along with the grain size analyses on the samples.

5.2 Geotechnical Design Criteria

Stearns-Roger Inc. has designed the access road with a 38 ft. wide surface and 12 ft. berms on each side, for a net width of 62 ft. between drainage ditches. No pavement design criteria have been established.

Roadway cuts will be made through weathered materials and relatively intact rock. The design slopes for weathered rock and soil must not exceed 1.5 to 1 vertical. Where massive layers of sandstone are encountered, this design may be steepened to 1:1 in those layers. Composite slopes may be constructed where the cut intersects weathered and resistant beds, and benching of the slope may be necessary to fit the topography. No loose or unconsolidated colluvium should be left on a slope greater than 1.5:1.

Prior to the construction of fills or embankments, the surface should be stripped of trees, stumps, roots and other surface objects and a minimum of one foot of soil and fractured rock should be removed. Holes from which obstructions have been removed should be backfilled with suitable materials and compacted to specified density. Conditions exposed by stripping which may indicate potential foundation instability should be examined prior to placement of the embankments. In particular, some exposures located on the proposed alignment near Station 195 + 00 indicate localized instability. This may require overexcavation to remove the unstable material and backfilling before the roadway fill can be made.

Embankments will be constructed from the sandstones and siltstones which comprise the Uinta Formation. As in the plant area embankment, roadway fills must be constructed so as to assure breakdown of rock and minimization of voids. This may be accomplished by lift thickness control and compactive effort. It is not possible to determine the number of passes necessary to obtain specified density levels without a field test section utilizing the contractors equipment. A tamping foot compactor comparable to the CAT 835B should be capable of compacting the materials. Side slopes of the compacted embankments should not exceed 1.5 to 1 vertical.

Golder Associates performed California Bearing Ratio (CBR) Tests on the compacted soil samples previously discussed. The results of these tests are shown on Figure 18. These values represent subgrade strength to be used in pavement design.

The roadway alignment follows the stream channel through the lower Gulch area. Side ditches should be adequately sized to handle the occasionally high flows which may result from thunderstorm activity. Embankment slopes must be protected from water flows which could scour away the fill. The particular areas which could be endangered lie between Station 190 + 00 and Station 227 + 00. Channel relocation away from the fills may be the simplest means of protection from Station 215 + 00 to 227 + 00. No local source of riprap is available on site, so elaborate embankment protection would be expensive.

The Colorado Department of Highways Design Office in Grand Junction was contacted with reference to highway department usage of the Uinta Sandstones as base courses for pavements. The Department has tested crushed sandstones

from a road cut near Ryan Gulch on the Piceance Creek Road in Rio Blanco County and found them suitable from a structural standpoint. If the Materials are properly compacted, and kept drained, they will perform satisfactorily. The 'R' value of the sandstone base course determined by CDH in their design method for the Ryan Gulch Sandstone is 84. The material was unsuitable for pavement aggregate in the wearing course.

The Highway Department has not elected to use this material in the upgrading of the Piceance Creek road because of restrictions in their design alignment which will not permit the increased depth of base course required for this material compared with base course material of crushed White River gravel. (They will haul their base course material from the White River.)

Insufficient sandstone will be available from the road cut to provide a base course for the entire length of roadway. Either a quarrying operation will be necessary or materials from the reclaim trench can be used. If the construction sequence does not permit direct utilization of materials from the trench excavation to the road base, it may still be most efficient to quarry sandstone from the trench site to minimize other surficial excavations on the Tract and lessen the yardage to be removed when the coarse ore storage area is constructed. The sandstones produced from the quarrying operation should be run through a crusher to provide a maximum size of 1.5 in. and a uniform gradation of smaller sized materials.

5.3 Construction Considerations

No unusual problems are foreseen in the road alignment proposed. Golder Associates did not plot the roadway cross sections to determine the maximum depth of cuts or fills or the relation of roadway width to the total width of the gulch bottom. The materials are believed to be rippable although some localized areas may require blasting. Since the bedrock to be excavated is near surface and therefore more possibly weathered, only an estimated 10 percent may require drilling and blasting.

No areas of excess moisture were observed on the alignment although one seep was located on the East side of the gulch approximately 200 ft. from the alignment.

From samples tested, and from previous work done by others, the maximum density ranges from 105 to 107 lb/cu. ft. at optimum moisture contents from 14 to 19 percent, as determined from Modified Proctor compaction tests (ASTM D1557 method D). Compaction control will be based on the type of equipment engaged on the project and field testing to verify the densities attained; 95 percent of Modified Proctor densities should be reached.

No in-place moisture contents were measured at the pits. The near surface moisture levels in the weathered sandstones appeared to be less than 10 percent. Although moisture levels will probably vary due to slope, exposure, depth of soil and vegetative cover, the average moisture content will probably lie below optimum levels and water may therefore be required at the fill.

It appears that all of the materials will exhibit swell from cut to fill. The in-place density of the rock was measured at about 130 lb/cu. ft. in the Mineability Study (14). Fractures and joints reduce that figure somewhat near the surface, but measured densities attainable in compaction tests were only 107 lb/cu. ft. This is less than originally expected, which requires a change in the original estimate of swell. The percentage of swell will average from 15 to 20 percent through the soil and rock cuts.

6.0 PICEANCE CREEK CROSSING

6.1 Subsurface Conditions

The distinction has been drawn between the Access Road and Piceance Creek Crossing due to dissimilar materials in the subsurface zones. The crossing will be built over loosely deposited sediments, primarily in the silt and sand size ranges. The sediments are layered and range in color from light brown to brown to gray and gray-green. Four borings were made across the valley including one at either side of the present stream and two additional locations across the meadow between the stream and the Piceance Creek Road. Figure 19 shows the location of the borings and a section through the sediments. Borehole logs are also included following the figures.

The valley floor beneath the sediments is probably sandstone and siltstone and lies from at least 70 to 75 ft. below surface. As expected, the groundwater level measured in the completed holes was only about five feet below the surface, which approximates the elevation difference of the meadow and the stream surface. Samples taken from the split-spoon drive sampler were saturated below a depth of about four feet.

Each hole was sampled at five foot intervals. Since the materials were basically similar, only the samples from borehole 4 were sent to the laboratory for analyses. The odd-numbered samples (10 ft. intervals) were analyzed for plasticity (clay content), grain size, and natural moisture content. The grain size distributions for these samples are presented in Figures 20 to 22. These samples coincided with the gravelly layers which are basically non-plastic materials.

6.2 Geotechnical Design Criteria

The crossing area will support some type of stream crossing structure and embankments on either end. The embankments will range in height from 8 to 25 ft. with bottom widths to 135 ft. Side slopes of the embankments should not exceed 1.5 horizontal to 1.0 vertical.

The stream crossing structure has not been defined as a bridge or

culvert at this time. If it is a bridge, end bearing piles should be used for the foundation. These piles should be driven into bedrock or the sand and gravel layers if sufficient resistance can be developed. The piles would have to be driven approximately 20 ft. into the sand and gravel to develop a capacity of 50 to 60 tons. The most probable type of piling available for the job would be precast concrete or a cast-in-place pile inside a driven tube.

Economic considerations will ultimately determine whether a bridge or an arch plate culvert should be installed. If the culvert is to be constructed, muck should be excavated to a depth of five feet below the invert elevation and a mat of free draining backfill placed and compacted to support the construction.

Prior to placement of the embankment, a layer of grass and soil should be scraped off the surface. No more than six inches should be removed. Light grading equipment should be employed for this work and the placement of the initial layers of fill because practically no resistance was encountered during sampling of material below 1.5 ft. depth. This indicates a very low bearing capacity. Heavy machinery will become mired and cause extensive disturbance to the area which is to be covered.

Fill placement should be slow and lift thickness should not exceed one foot. The initial layers of fill should be of graded materials that will assure free drainage of the sediments. Settlements will occur concurrently with fill placement. The silt and sand sediments should drain quickly and consolidate to a competent foundation material. The fill placement should be controlled to assure against too rapid loading and the failure which would accompany it. If placed slowly enough, the fill will cause compression of the mass of the subgrade and will force out water to densify the sediments. Placement of the fill in one foot horizontal lifts completely across the valley should sufficiently control the rate of rise to a safe level.

6.3 Construction Considerations

Lightweight equipment must be used during initial fill placement. Special low ground bearing pressure tractors may be advisable. Heavy

scrapers (CAT 651 or equiv.) would cause pumping of the subgrade and probably be unable to negotiate the surface. End dumping and advancement of the initial three to four foot thick working mat with bulldozers would be preferable to scraper traffic. Due to the extensive depths of the loose sediments, a mired machine could mean a difficult extraction problem.

Temporary crossing of the stream may be difficult in order to begin the North side fill prior to construction of the bridge (culvert). Temporary diversion of the stream around the culvert may be difficult to repair.

Type II or Type V cement should be used in concreted hydraulic control structures in the crossing area.

CLASSIFICATION OF FRACTURE DENSITY

Classification is based upon the number of natural fractures, regardless of orientation or origin (bedding plane, regional, fault, etc.) intersected by a one-foot vertical traverse over the exposure or unit being studied.

<u>Category</u>	<u>Description</u>
UNFRACTURED	0 fractures per foot
SLIGHTLY FRACTURED	1 - 5 fractures per foot
MODERATELY FRACTURED	6 - 20 fractures per foot
HIGHLY FRACTURED	21 - 30 fractures per foot
EXTREMELY FRACTURED	30 fractures per foot

If the rock unit significantly changes in fracture density from top to bottom (eg. 35 fpf at top, to 15 fpf at base), i.e. increases or decreases continuously with depth, fracture density is described as (in this case) extremely to moderately fractured.

If there is no tendency for increase or decrease, but there is enough variation that measured fracture densities are in different categories, then a mean is calculated and the description based upon the category into which the mean fits.

CLASSIFICATION OF ROCK HARDNESS

(After Jennings/N.C.C.M.)

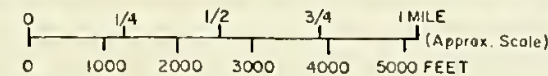
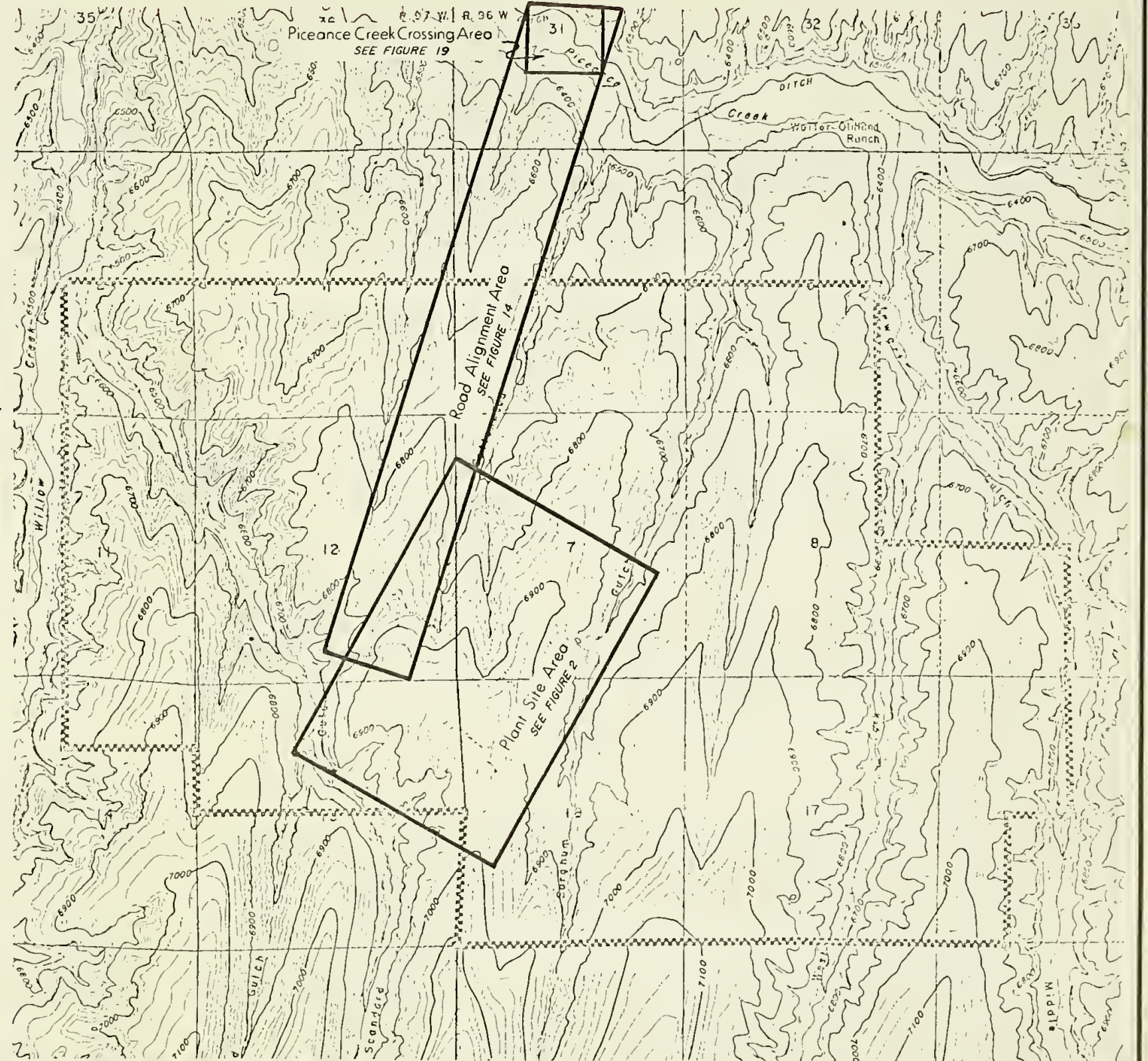
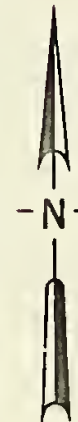
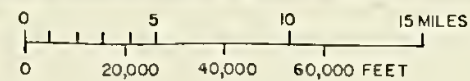
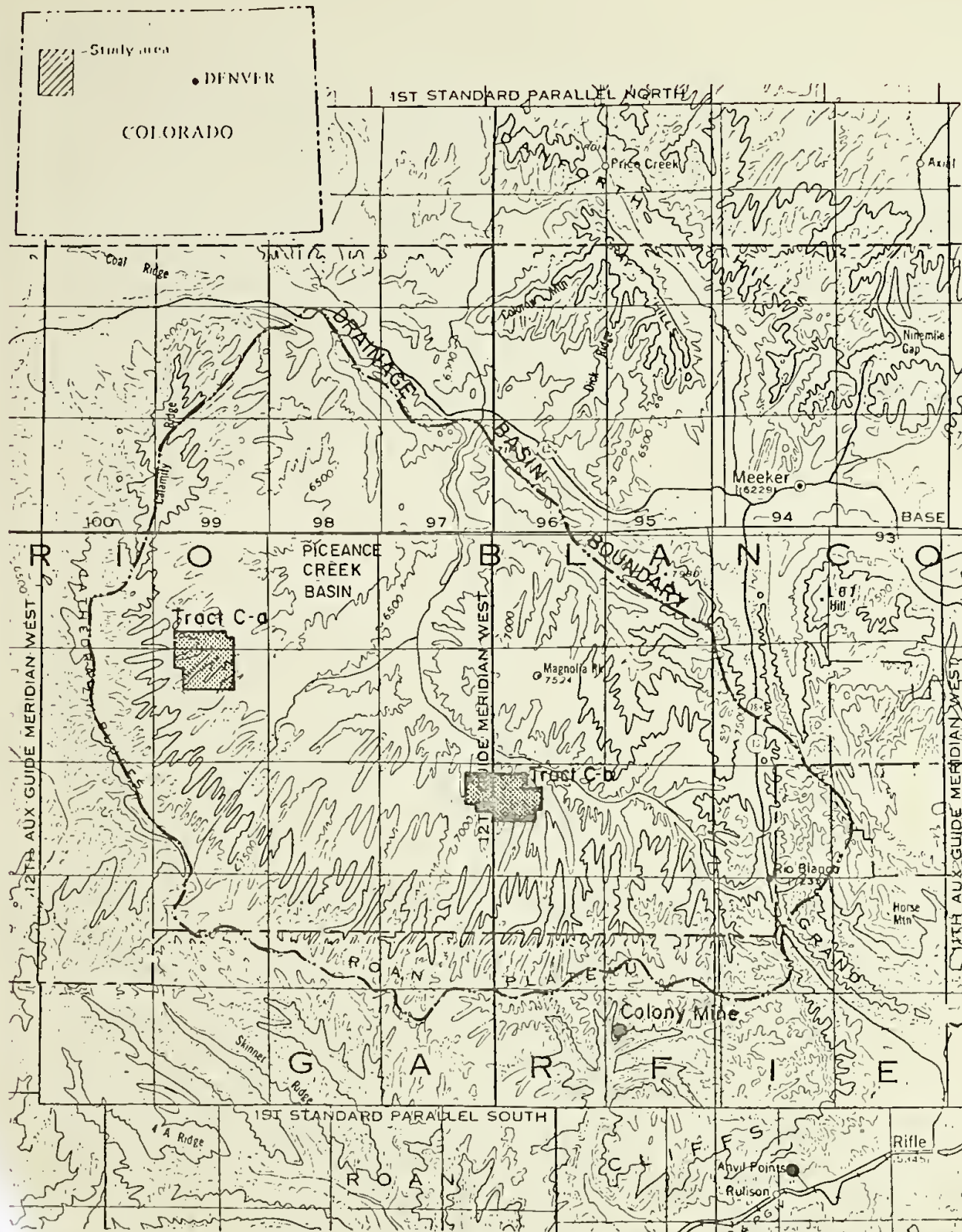
<u>CATEGORY</u>	<u>MECHANICAL TEST</u>	<u>CODE</u>
Very Soft Rock	Material crumbles under firm blows with the sharp end of a geological pick and can be peeled off with a knife; it is too hard to cut a triaxial sample by hand.	R1
Soft Rock	Can just be scraped and peeled with a knife; indentations 1.6 mm. to 3.2 mm. (1/16" to 1/8") show in the specimen with firm blows of the pick point.	R2
Hard Rock	Cannot be scraped or peeled with a knife; hand-held specimen can be broken with the hammer end of a geological pick with a single firm blow.	R3
Very Hard Rock	Hand-held specimen breaks with hammer end of pick under more than one blow.	R4
Extremely Hard Rock	Specimen requires many blows with geological pick to break through intact material.	R5

CLASSIFICATION OF WEATHERING

<u>CATEGORY</u>	<u>DESCRIPTION</u>	<u>CODE</u>
Fresh	The rock shows no discoloration, loss of strength, or any other effect due to weathering.	FR
Fresh-jointed	Fresh with weathered joints.	FJ
Slightly-weathered	The rock is slightly discolored and noticeably weakened or lower in strength than fresh rock.	SW
Moderately-weathered	The rock is discolored and noticeably weakened, but NX core or 5 cm fragments cannot be broken by hand across the rock fabric.	MW
Highly-weathered	The rock is usually discolored and weakened to such an extent that NX core or 5 cm fragments can be broken up readily by hand across the fabric. Wet strength is usually much lower than dry strength.	HW
Completely-weathered	The rock is discolored and completely changed to a soil, but original fabric is mainly preserved.	CW

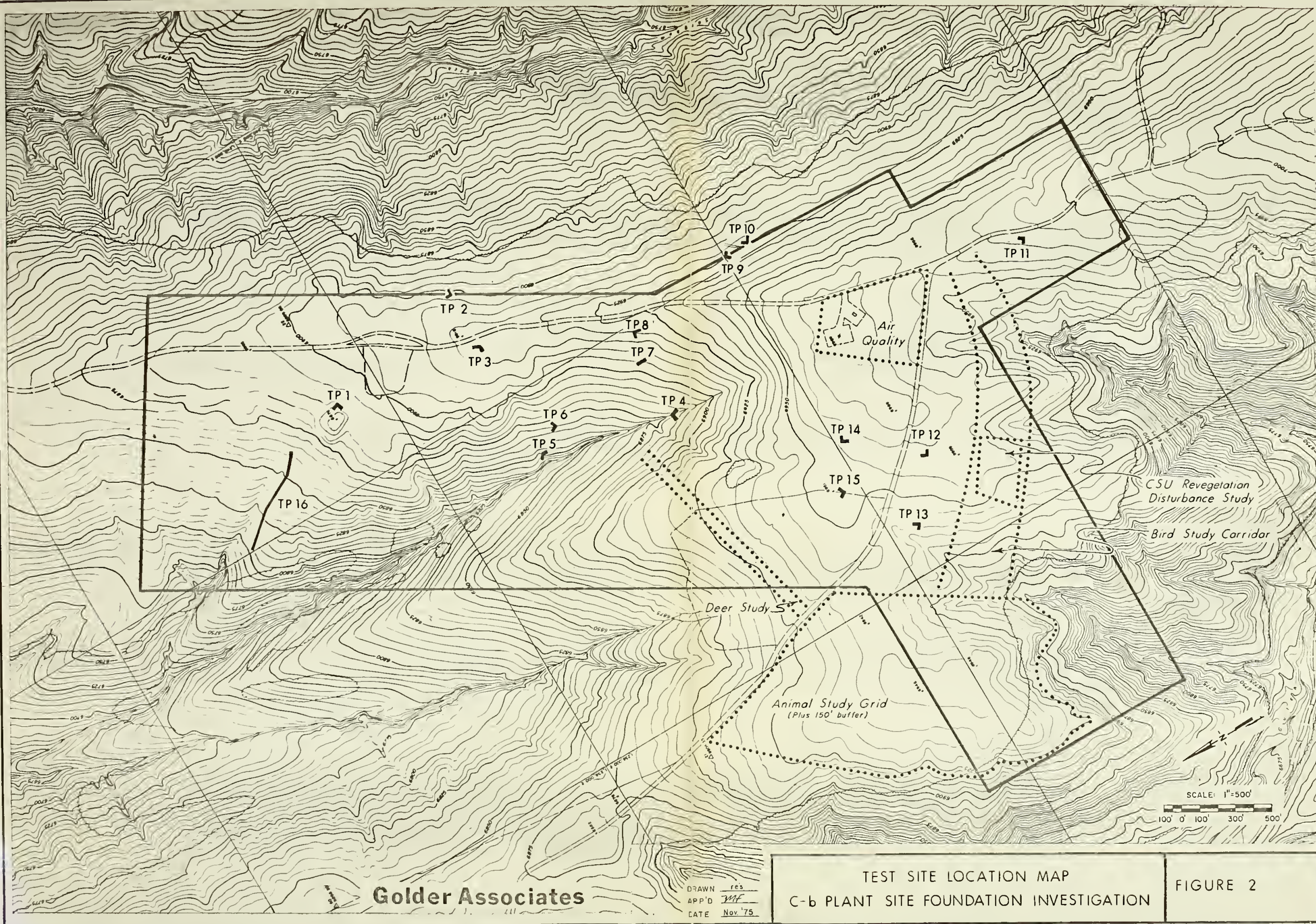
KEY PLANS

FIGURE 1



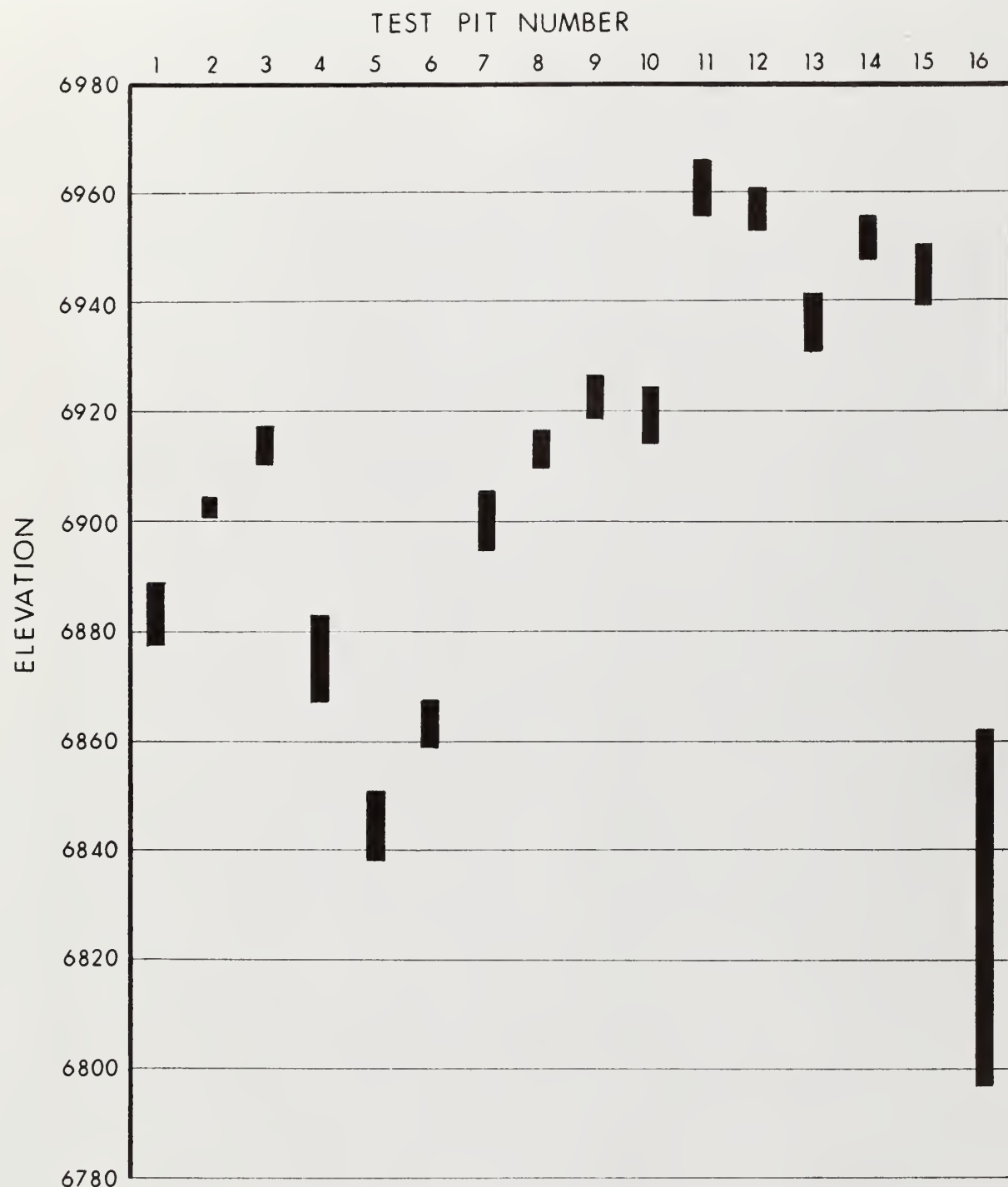
Golder Associates

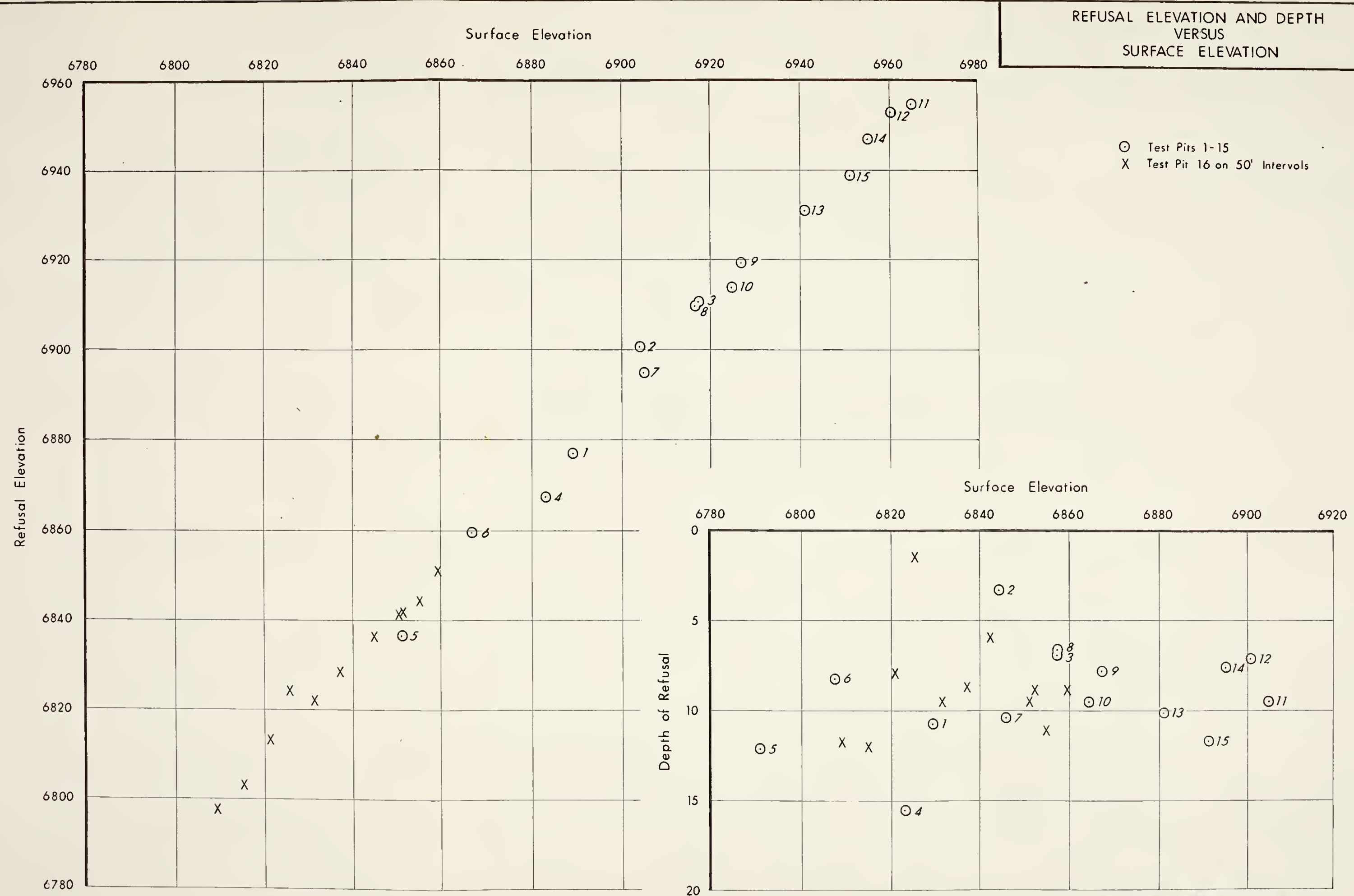
DRAWN res
APP'D M
DATE Nov. 75



SUMMARY OF VERTICAL SECTIONS
IN TEST PITS

FIGURE 3

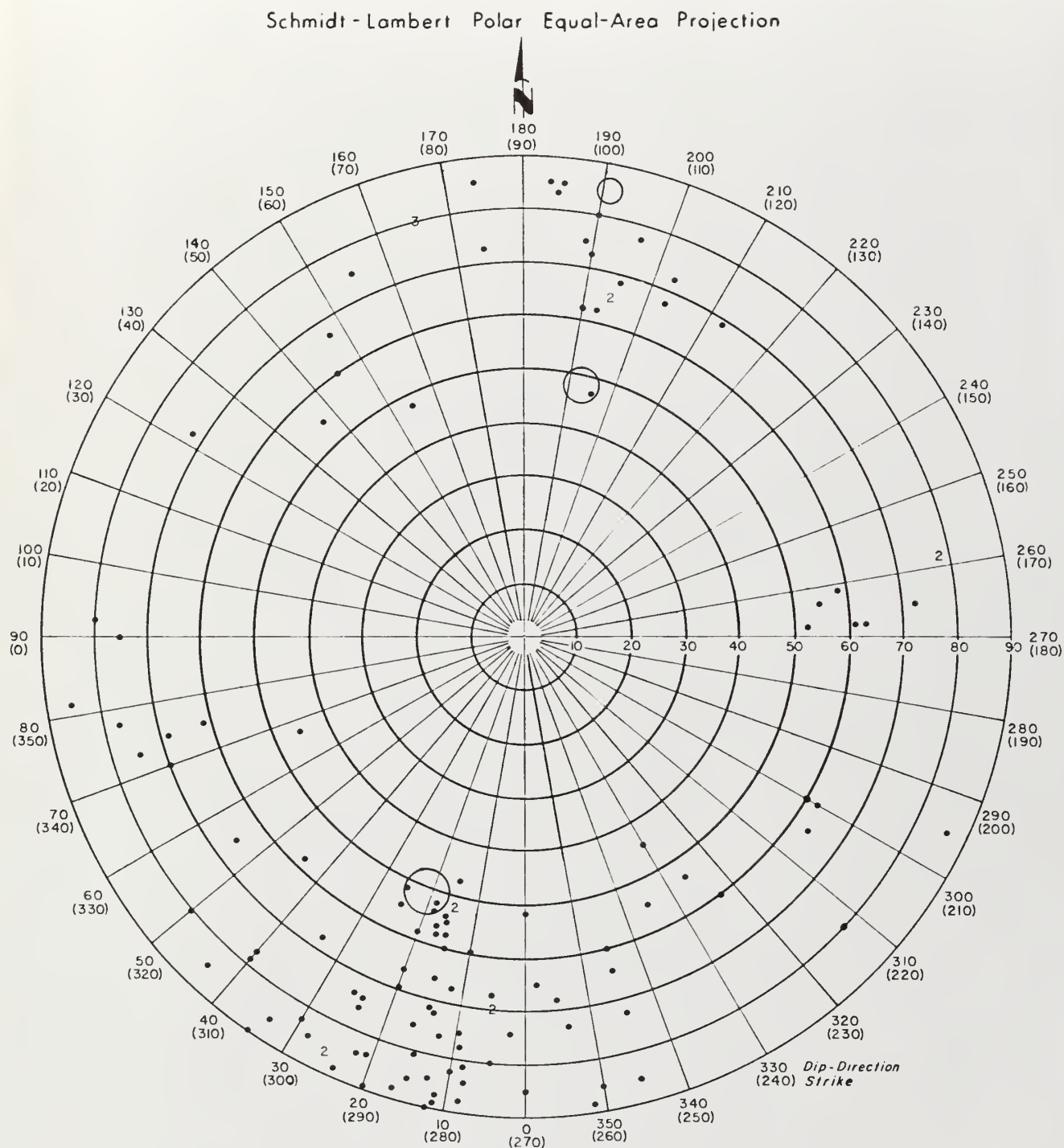




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FRACTURE DATA: TEST PITS 1-15

FIGURE 5



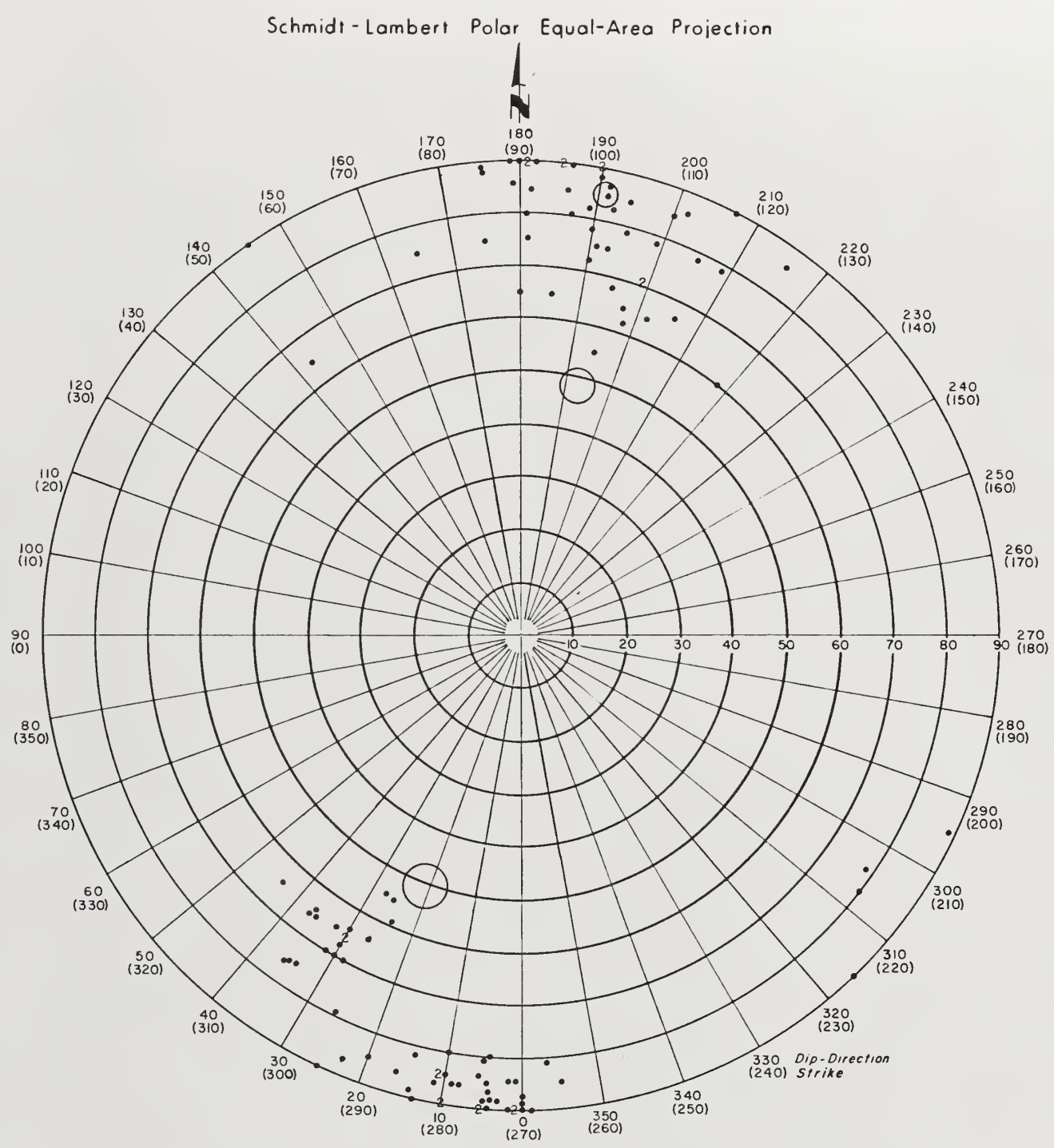
NOTE:

- Major Joint Set (51°/021°)
- Intermediate Joint Set (48°/193°)
- Minor Joint Set (85°/191°)

Taken from Fig. 3-7, Vol. III B, C-b Mineability Study.
(Inclined Core Hole Fractures)

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Drawn res
App'd MM
Date Dec '75



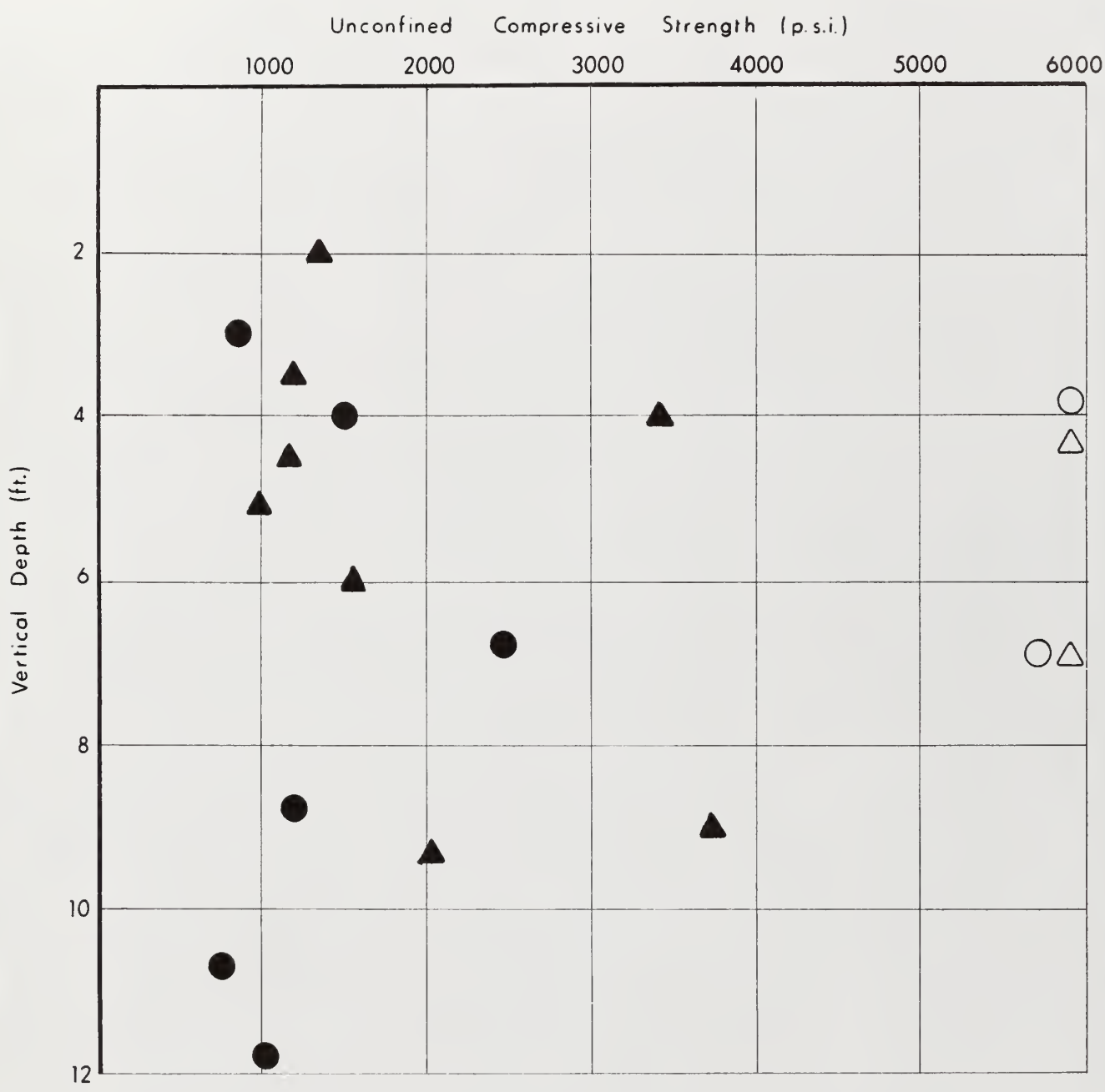
NOTE:

- Major Joint Set (51°/021°)
- Intermediate Joint Set (48°/193°)
- Minor Joint Set (85°/191°)

Token from Fig. 3-7, Vol. III B, C-b Mineability Study.
(Inclined Core Hole Fractures)

UNCONFINED COMPRESSIVE STRENGTHS
FROM TEST PITS

FIGURE 7



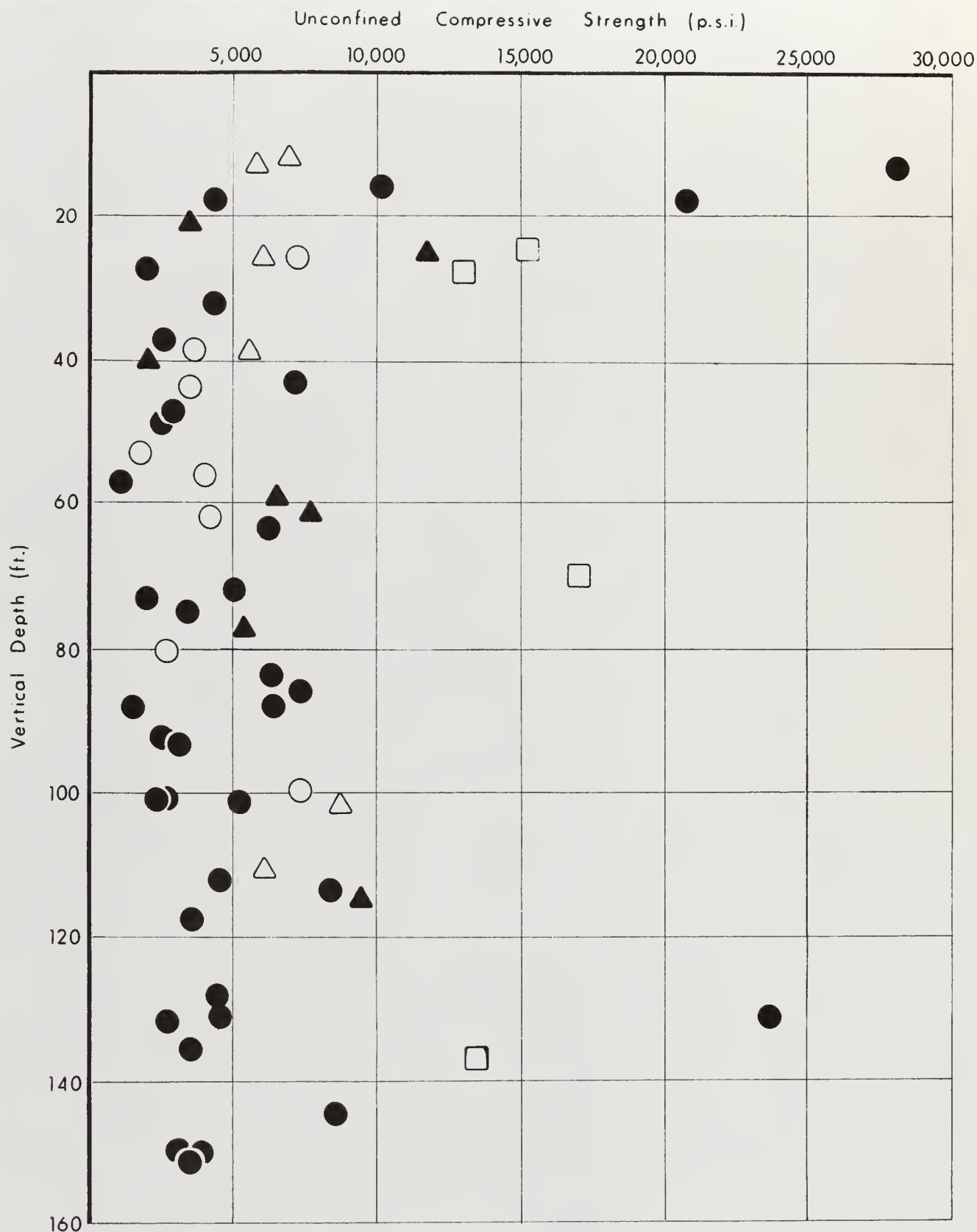
Sandstone Siltstone
● ▲
○ △ In excess of 6000 p.s.i.

Golder Associates

Drawn res
App'd MF
Date Nov. '75

SUMMARY OF PREVIOUS DATA ON UNCONFINED COMPRESSIVE STRENGTH

FIGURE 8

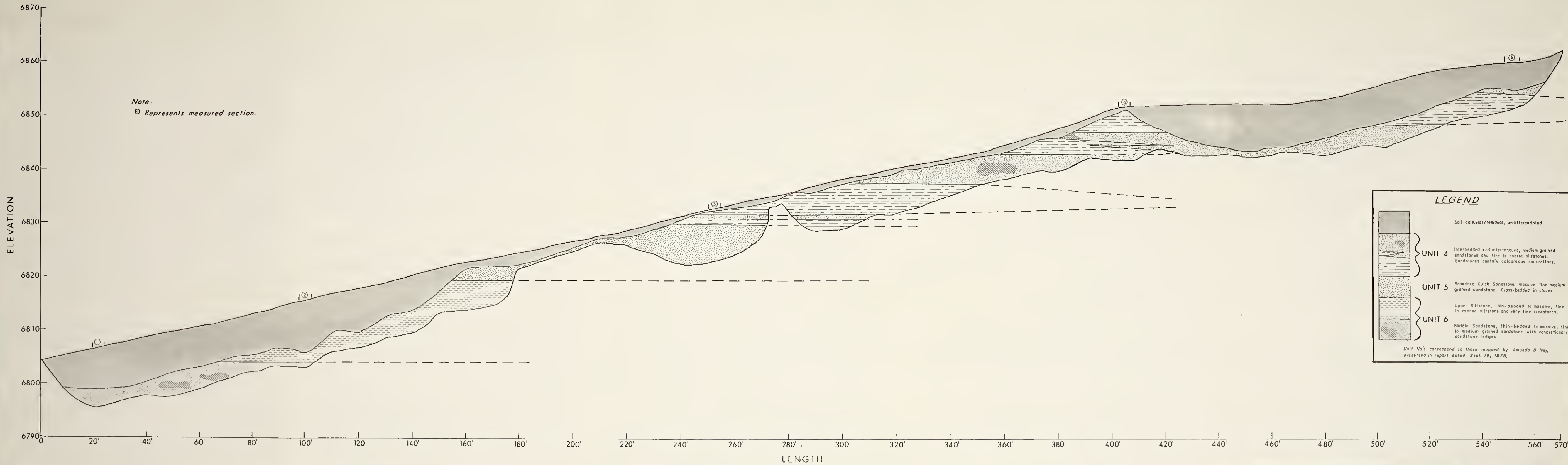


LEGEND:

Sandstone: ●
 Siltstone: ▲
 Shale: ■
 Cb Tract NQ Holes: ○
 Porachute Creek: △

Golder Associates

Drawn: res
 App'd: *MF*
 Date: Nov '75

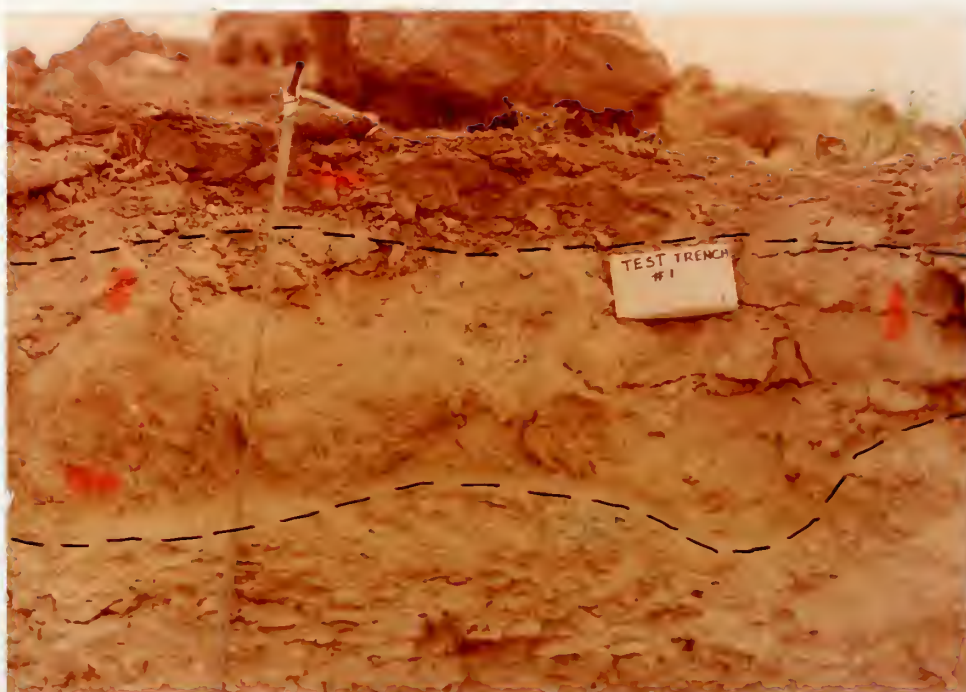


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DRAWN res
APP'D ME
DATE Nov. 75

DIAGRAMMATIC CROSS SECTION AND STRATIGRAPHY
OF TEST PIT 16, LOOKING NORTH

FIGURE 9

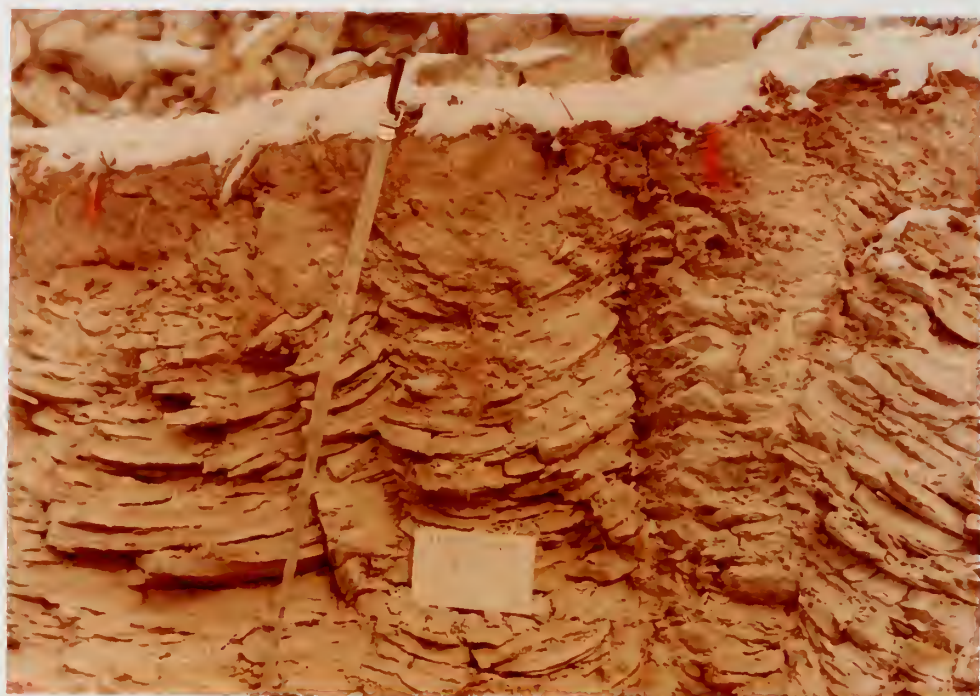


(a)

Typical soil profile showing topsoil, residual/colluvial and residual soils.

(b)

Typical "weathered zone" in siltstone showing light color of the rocks and garland effects of frost action.



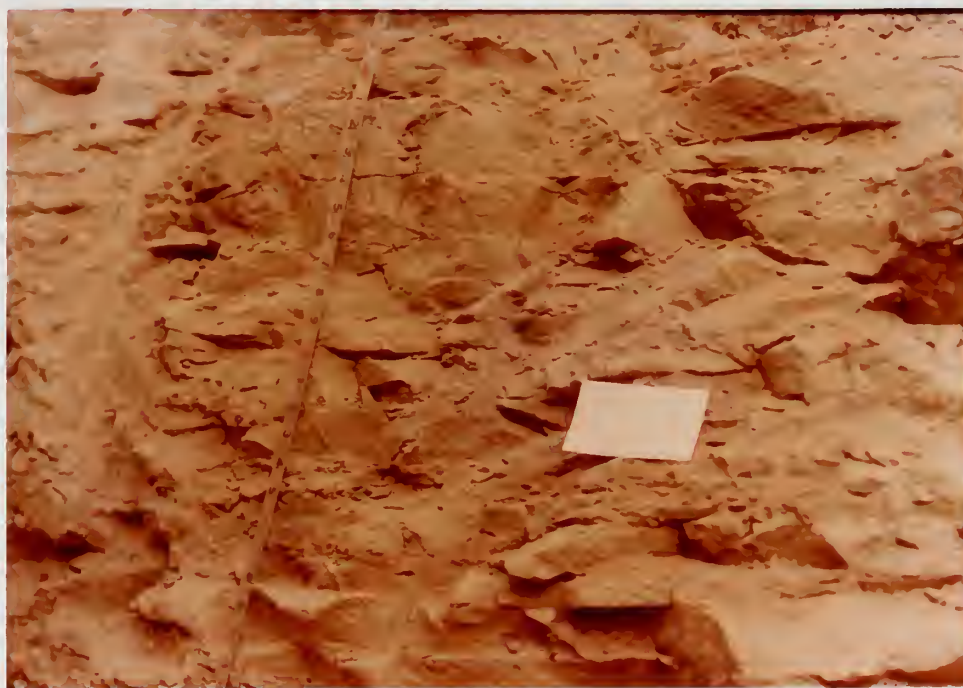


(a)

Fracturing of sandstone in Test Pit 16, Profile 3. Dashed line indicates level at which fracture density decreases markedly.

(b)

Massive sandstones showing backhoe grooves characteristic of "soft refusal", and closed, moderate fracturing.





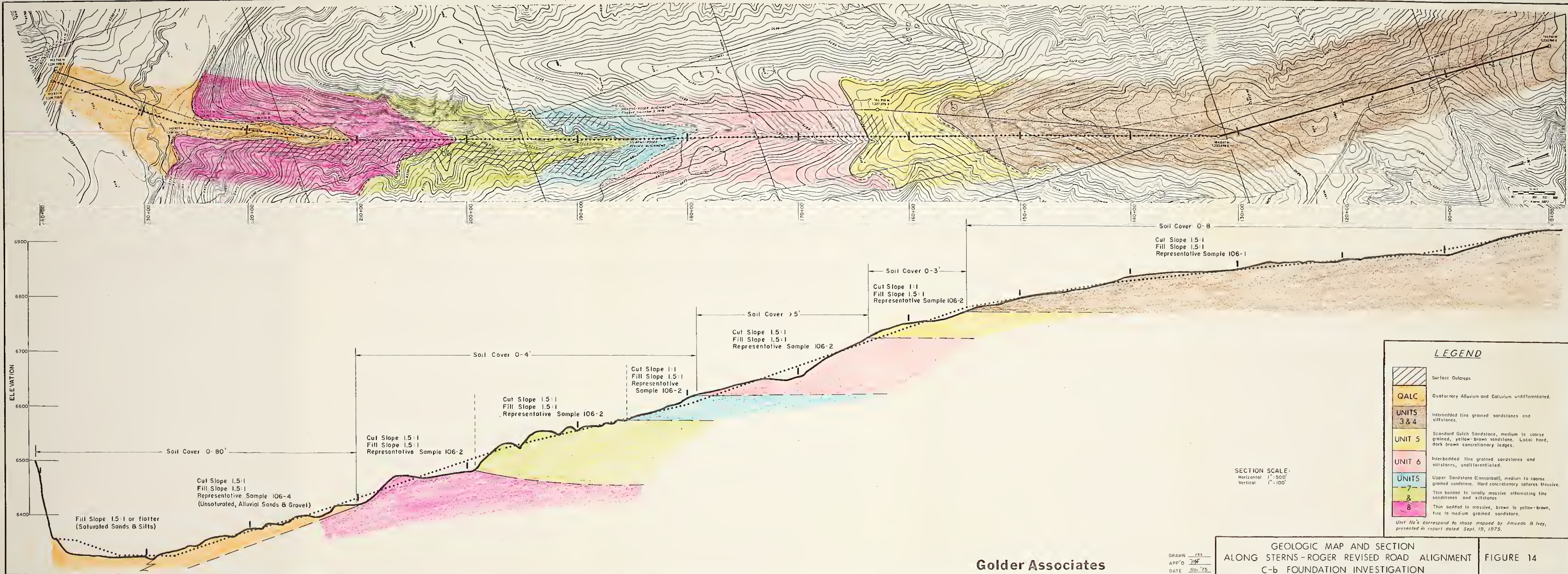
(a)

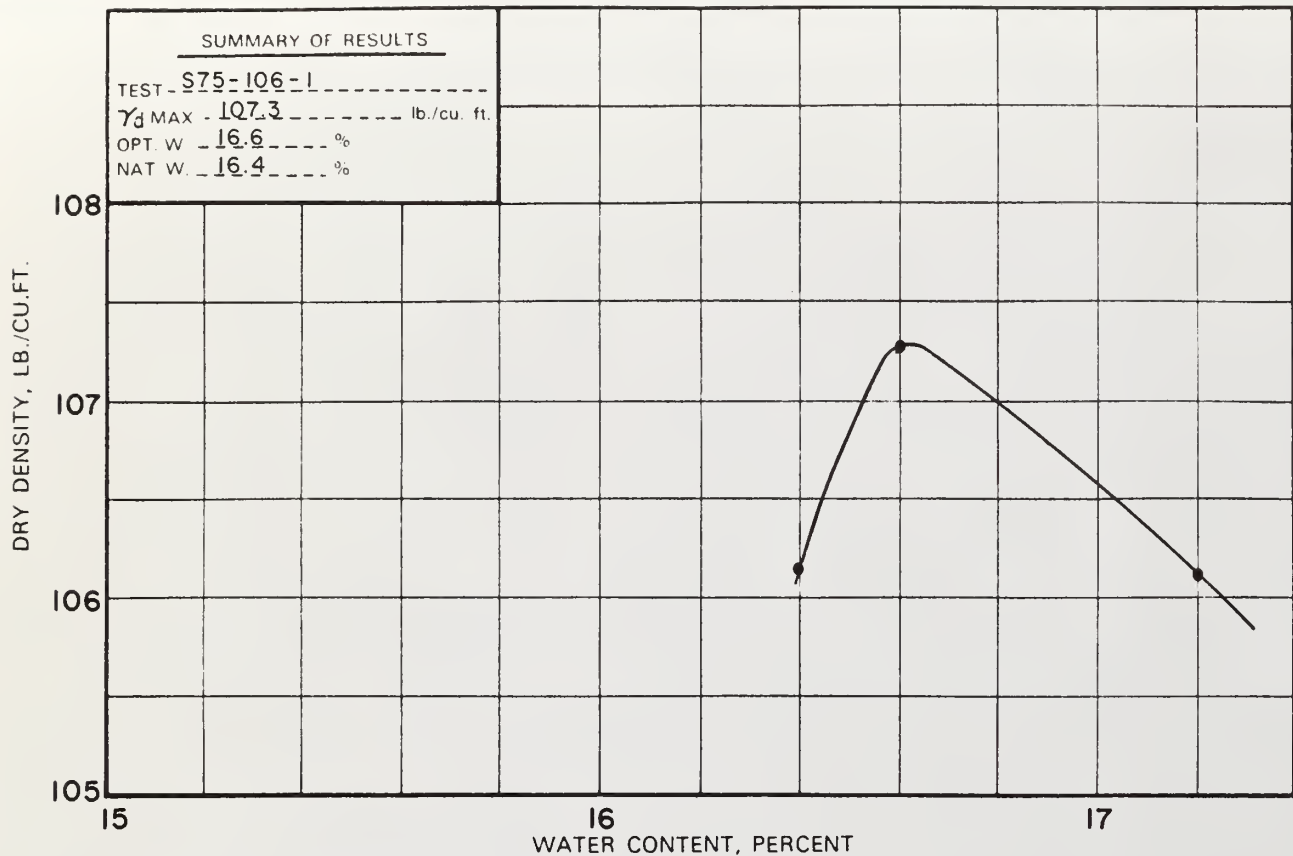
Hard shelf of sandstone underlain by siltstone in Test Pit 16 illustrating the contact between Units 5 and 6.



(b)

South facing wall of Test Pit 5 showing fractures indicating bedrock movement to the west.

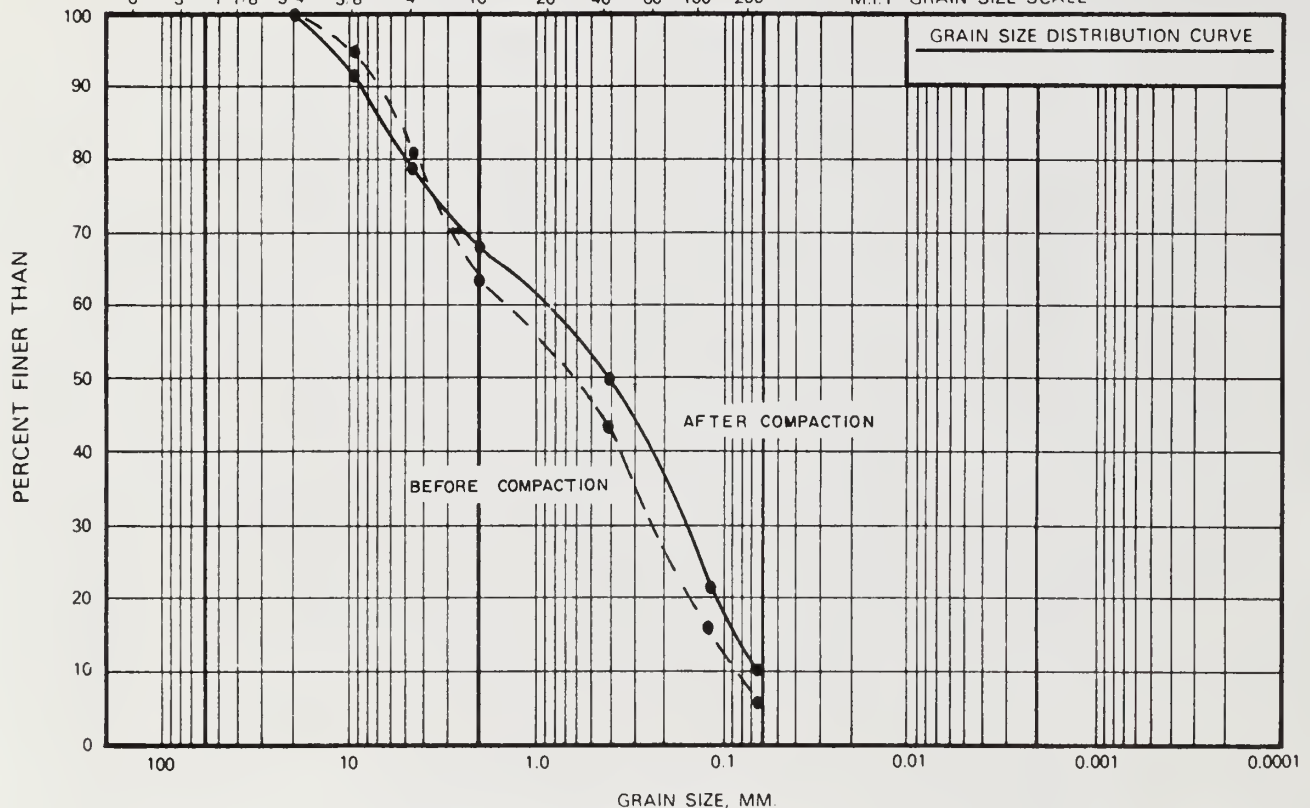




TEST RUN ON - 3/4" MATERIAL IN ACCORDANCE WITH ASTM D1557 METHOD D.

SIZE OF OPENING, INCHES U.S.S. SIEVE SIZE, MESHES/INCH

6" 3" 1-1/8" 3/4" 3/8" 4 10 20 40 60 100 200 M.I.T. GRAIN SIZE SCALE

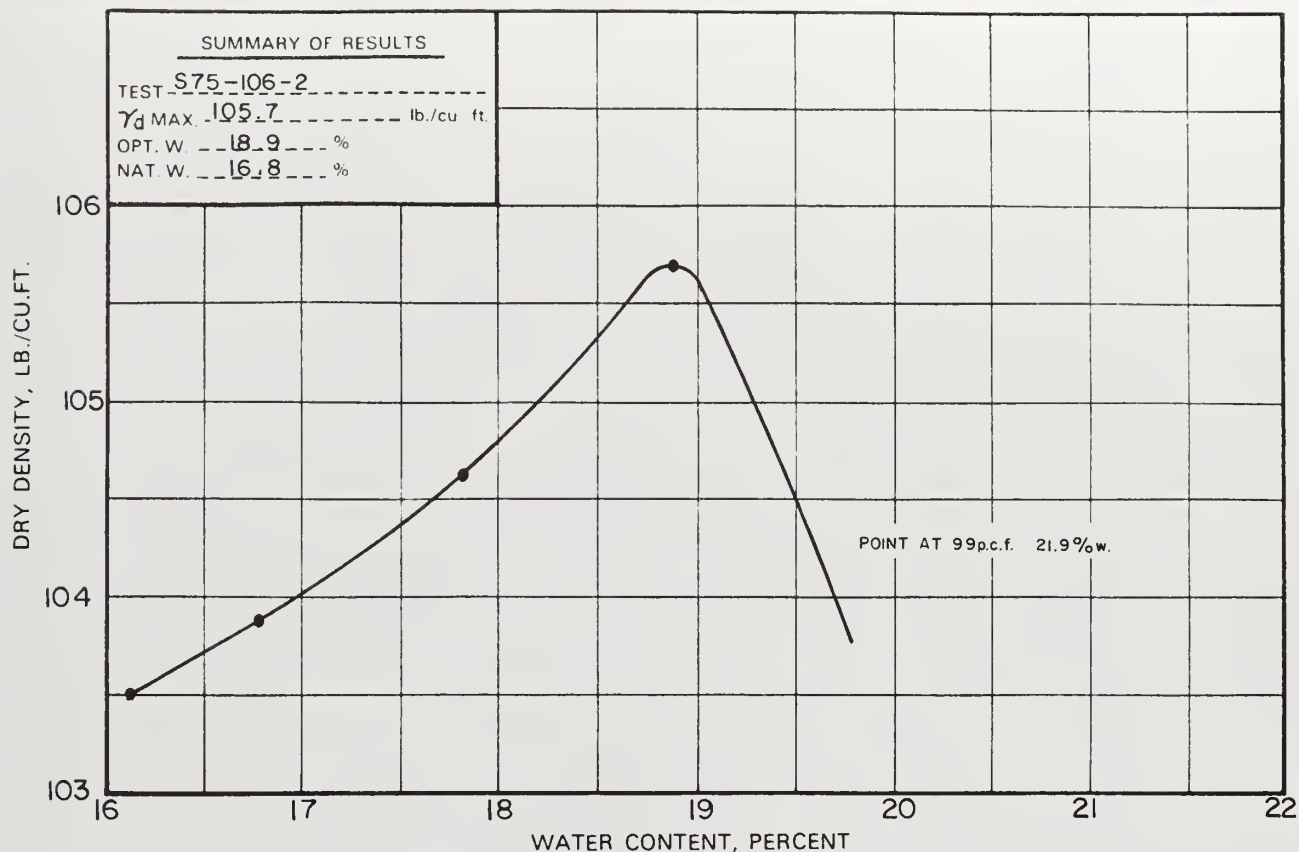


COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

Project No. S75106
Project Cb Tract Foundations

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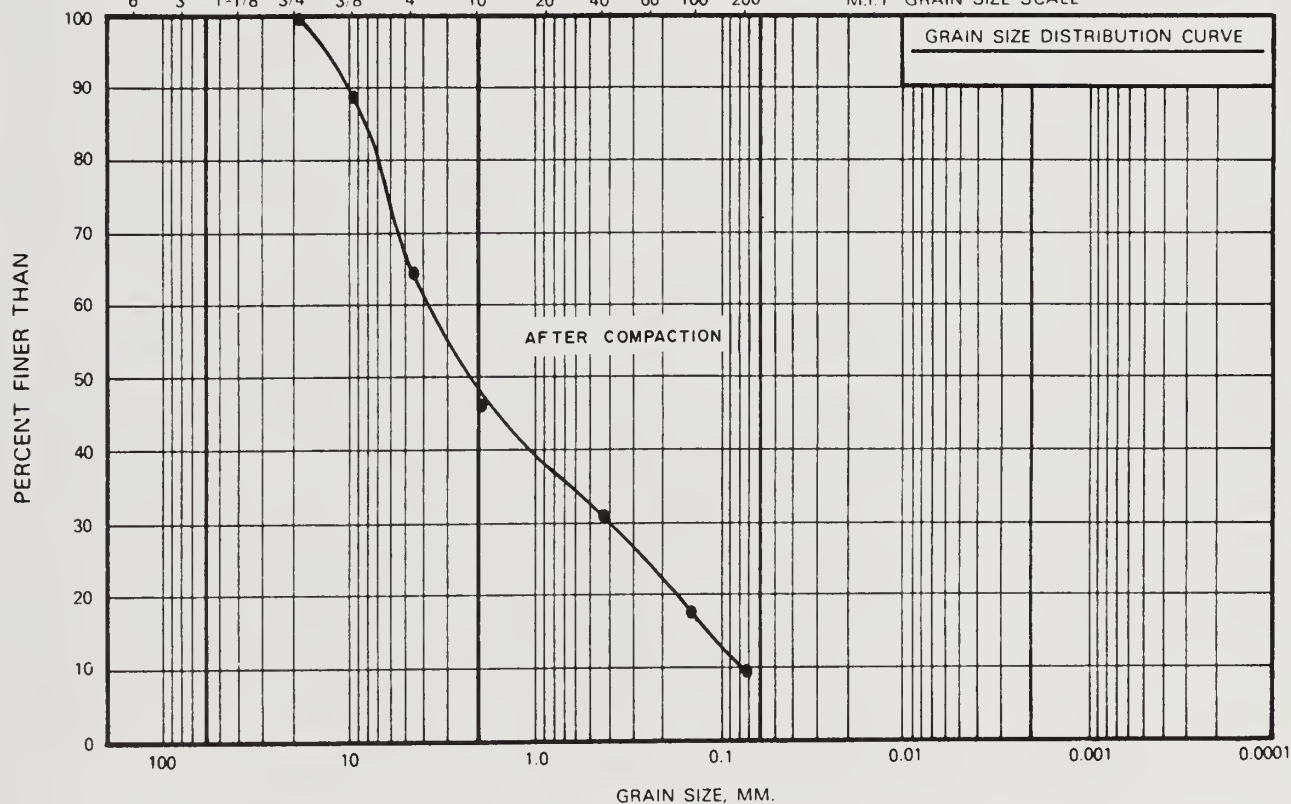
Date November 26, 1975
By PS



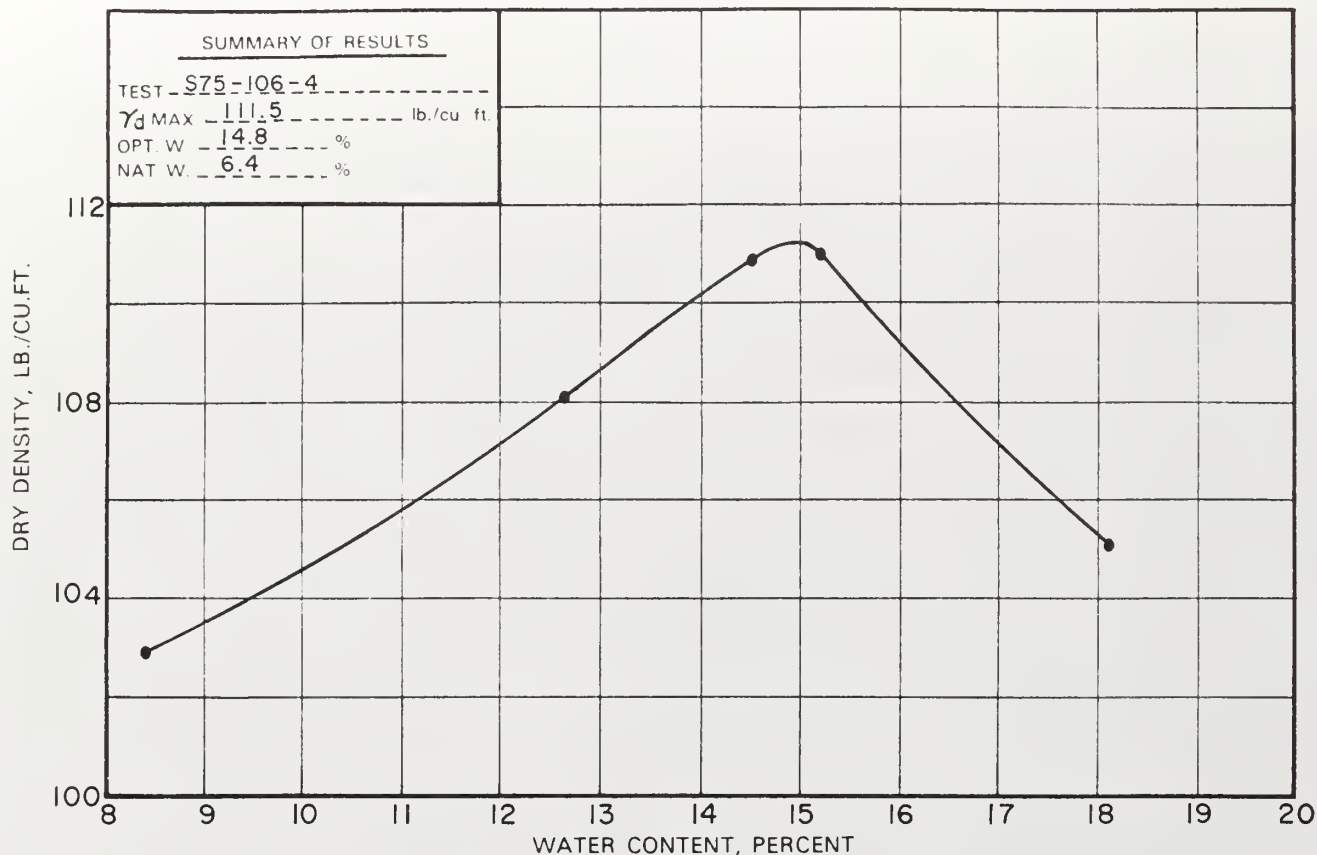
TEST RUN ON - 3/4" MATERIAL IN ACCORDANCE WITH ASTM D1557 METHOD D.

SIZE OF OPENING, INCHES U.S.S. SIEVE SIZE, MESHES/INCH

6" 3" 1-1/8" 3/4" 3/8" 4 10 20 40 60 100 200 M.I.T. GRAIN SIZE SCALE

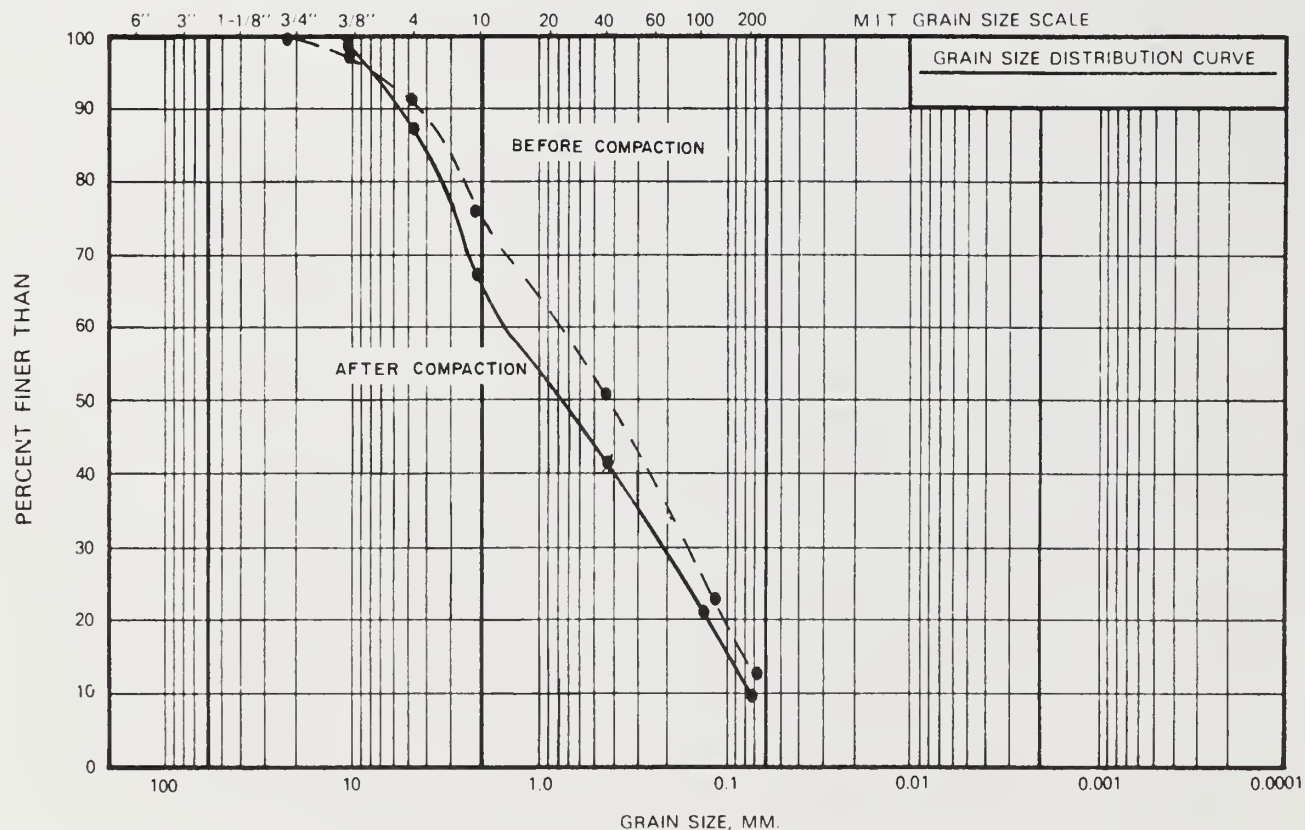


COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	



TEST RUN ON -3/4" MATERIAL IN ACCORDANCE WITH ASTM D1557 METHOD D.

SIZE OF OPENING, INCHES U.S.S. SIEVE SIZE, MESHES/INCH

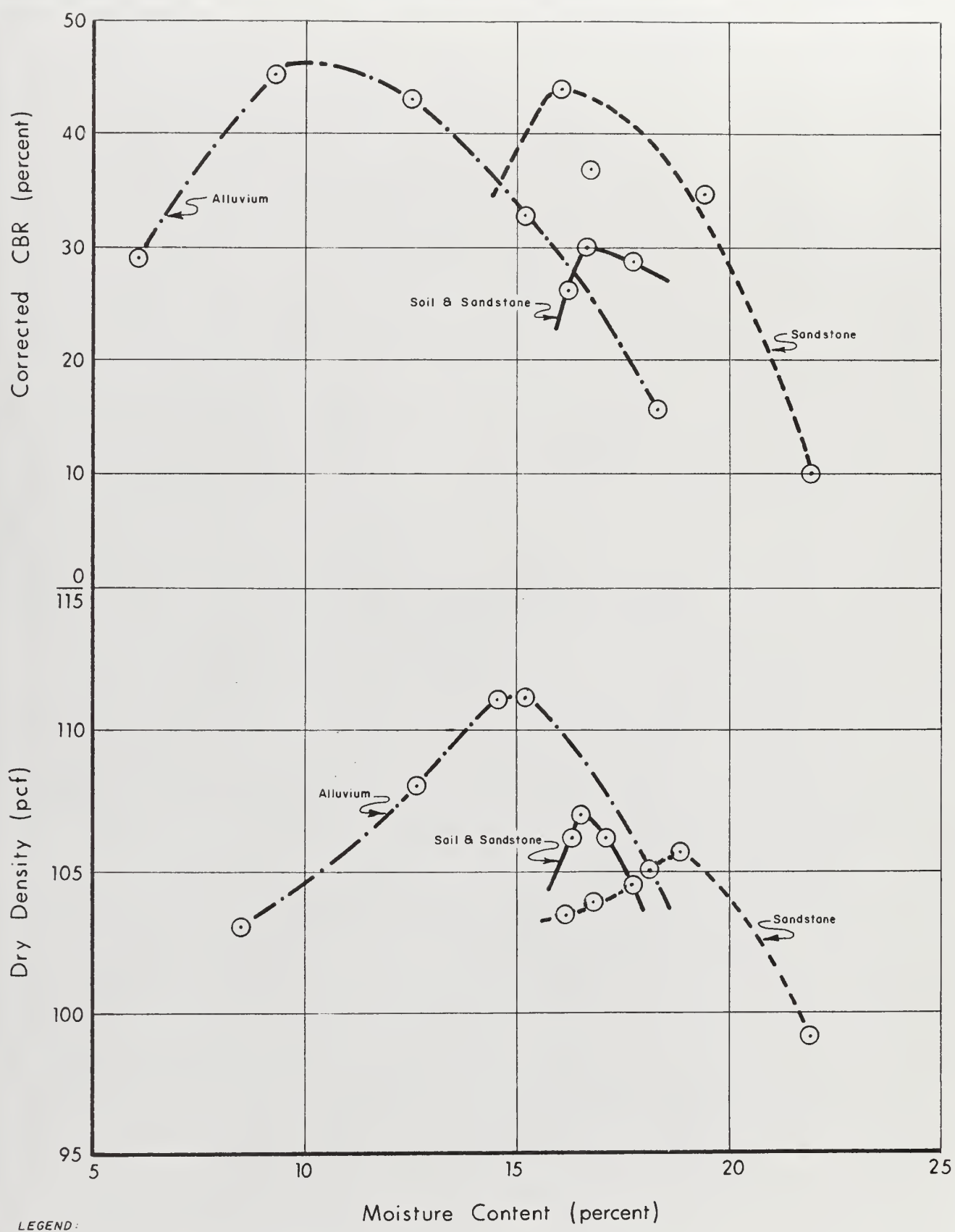


COBBLE SIZE	COARSE GRAVEL SIZE	MEDIUM GRAVEL SIZE	FINE GRAVEL SIZE	COARSE SAND SIZE	MEDIUM SAND SIZE	FINE SAND SIZE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

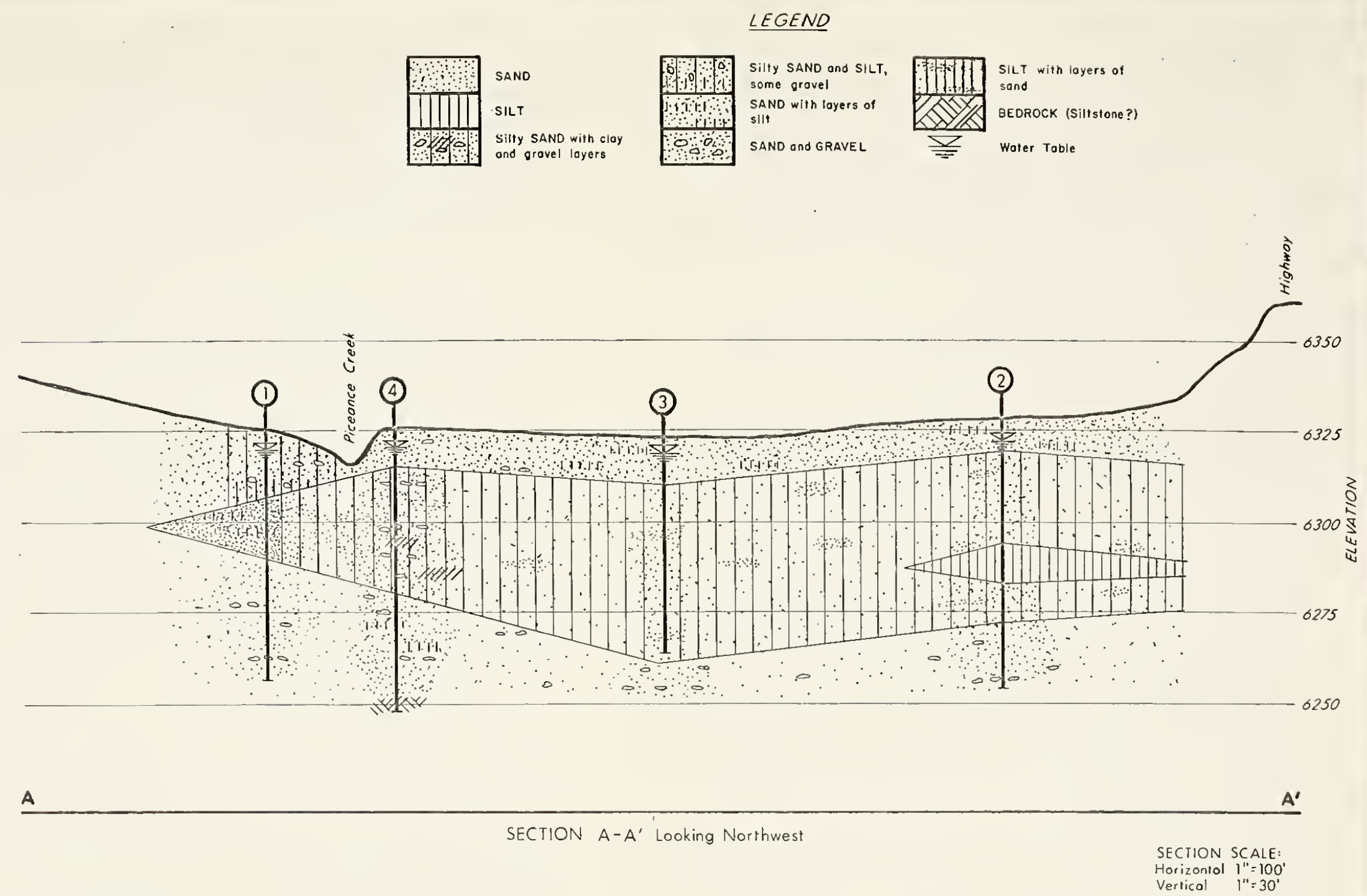
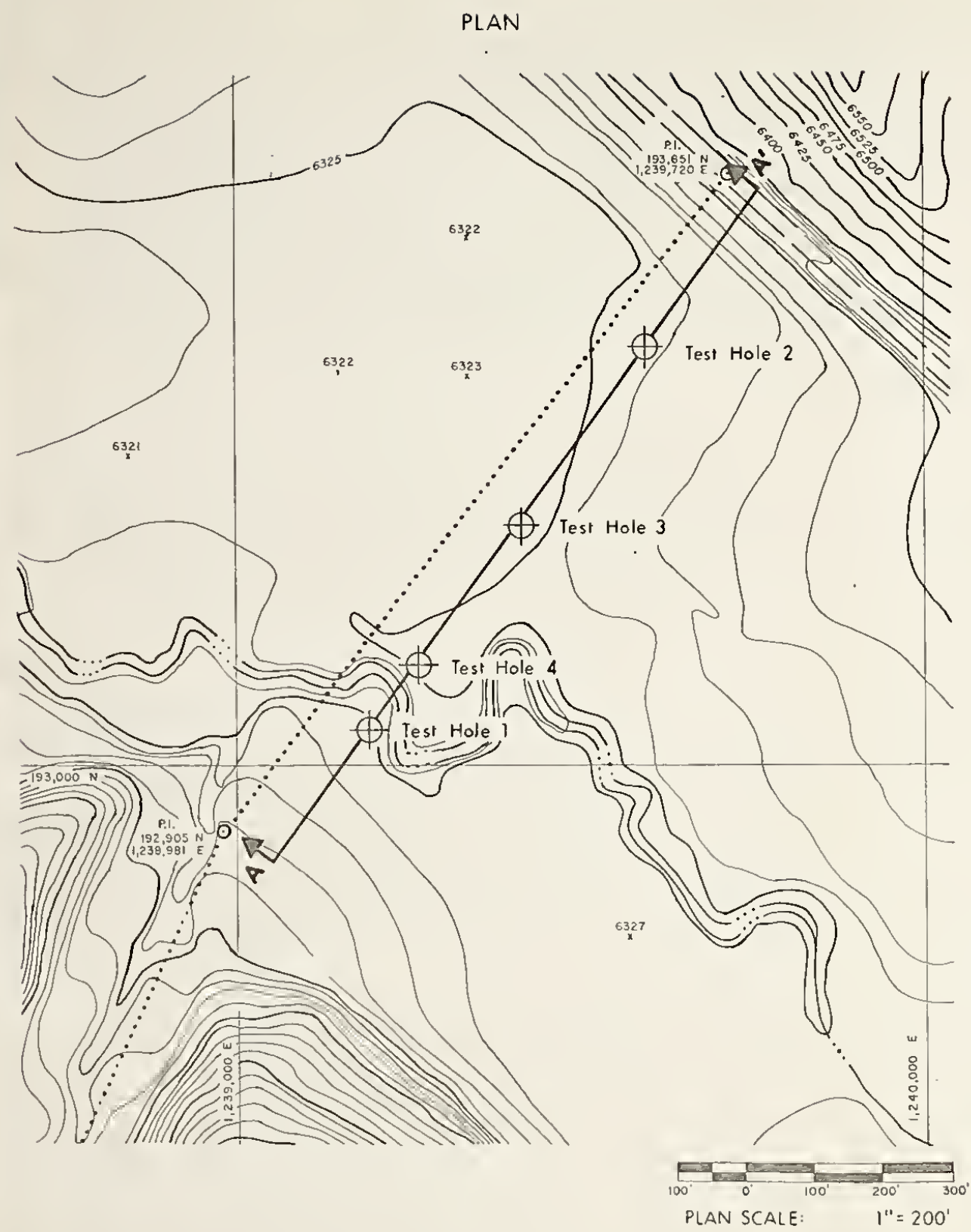
Project No. S75106
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By PS



LEGEND:
SAMPLE 106-1
SAMPLE 106-2
SAMPLE 106-4



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DATE Dec. 75

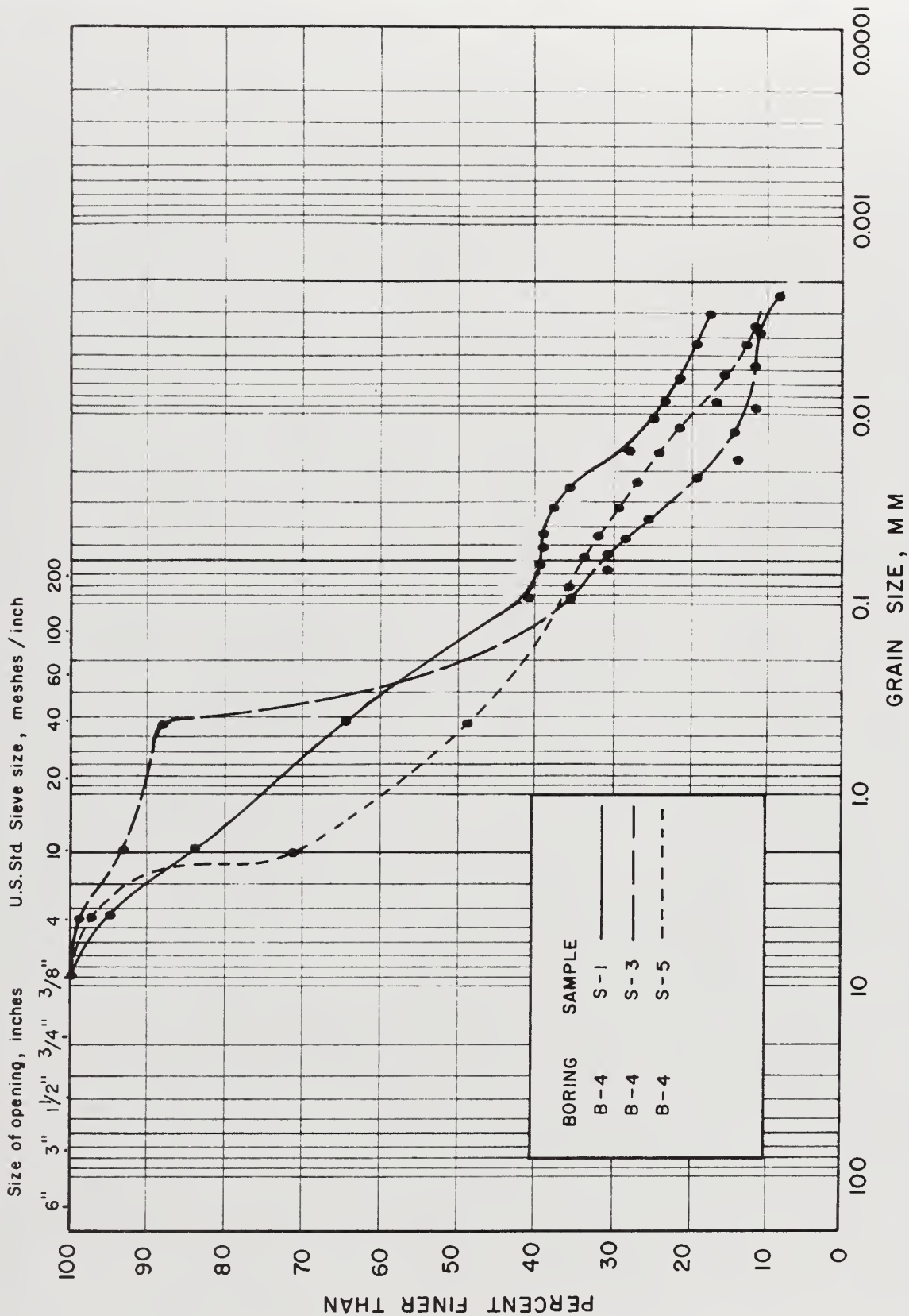
BOREHOLE PLAN AND STRATIGRAPHY

FIGURE 19

GRAIN SIZE DISTRIBUTION

FIGURE 20

M. I. T. GRAIN SIZE SCALE



COBBLE SIZE	GRAVEL SIZE			SAND SIZE			SILT SIZE		CLAY SIZE	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	FINE GRAINED			

Project No. S75106

Project Cb Tract Foundations

Golder Associates

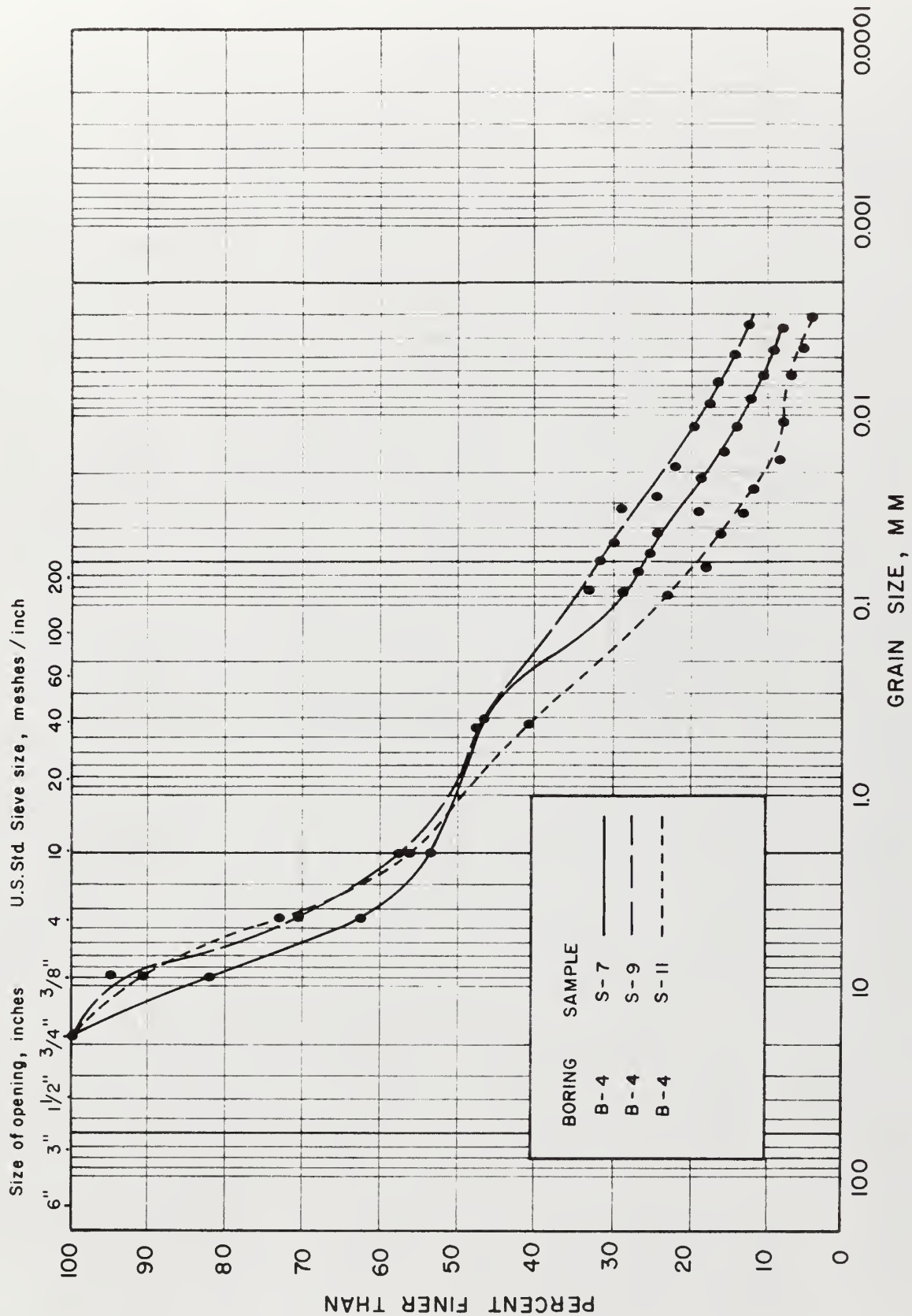
Date November 26, 1975

By PS

GRAIN SIZE DISTRIBUTION

FIGURE 21

M. I. T. GRAIN SIZE SCALE



COBBLE SIZE	COARSE	MEDIUM	FINE	SAND SIZE			SILT SIZE	FINE GRAINED		CLAY SIZE
	GRAVEL SIZE			COARSE	MEDIUM	FINE				

Project No. S75106

Project Cb Tract Foundations

Golder Associates

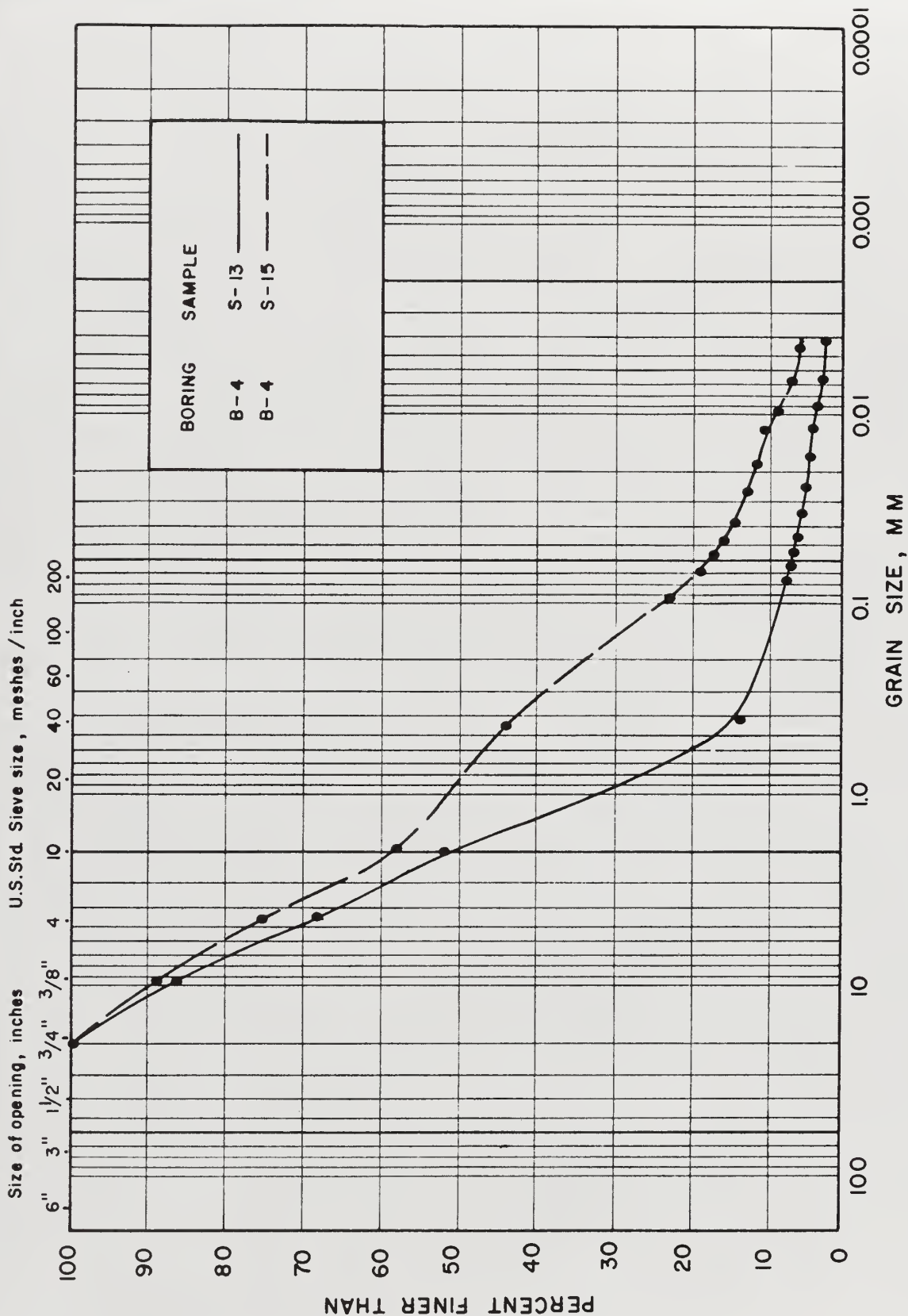
Date November 26, 1975

By *PS*

GRAIN SIZE DISTRIBUTION

FIGURE 22

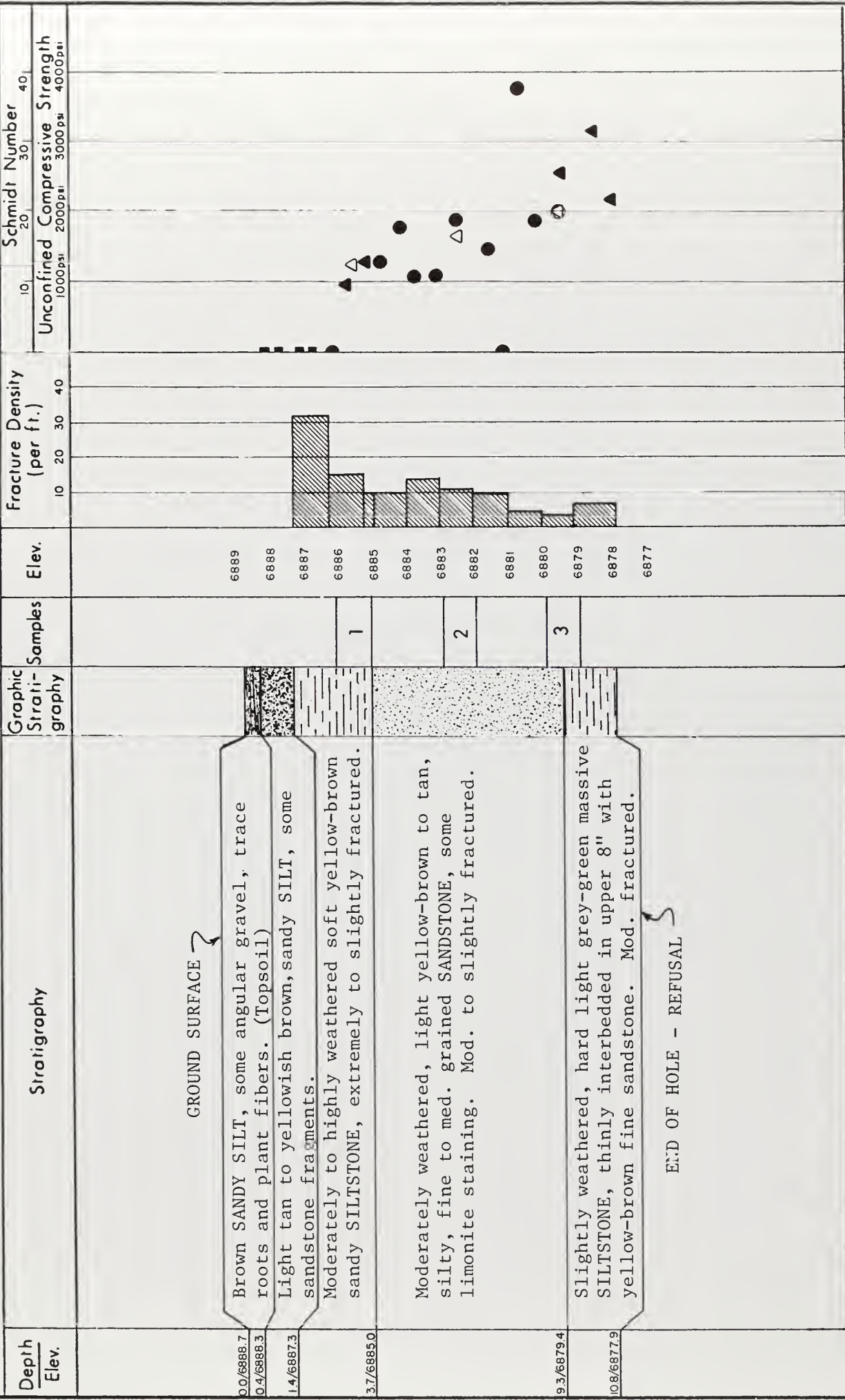
M.I.T. GRAIN SIZE SCALE



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

RECORD OF TEST PIT No. 1

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 9, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

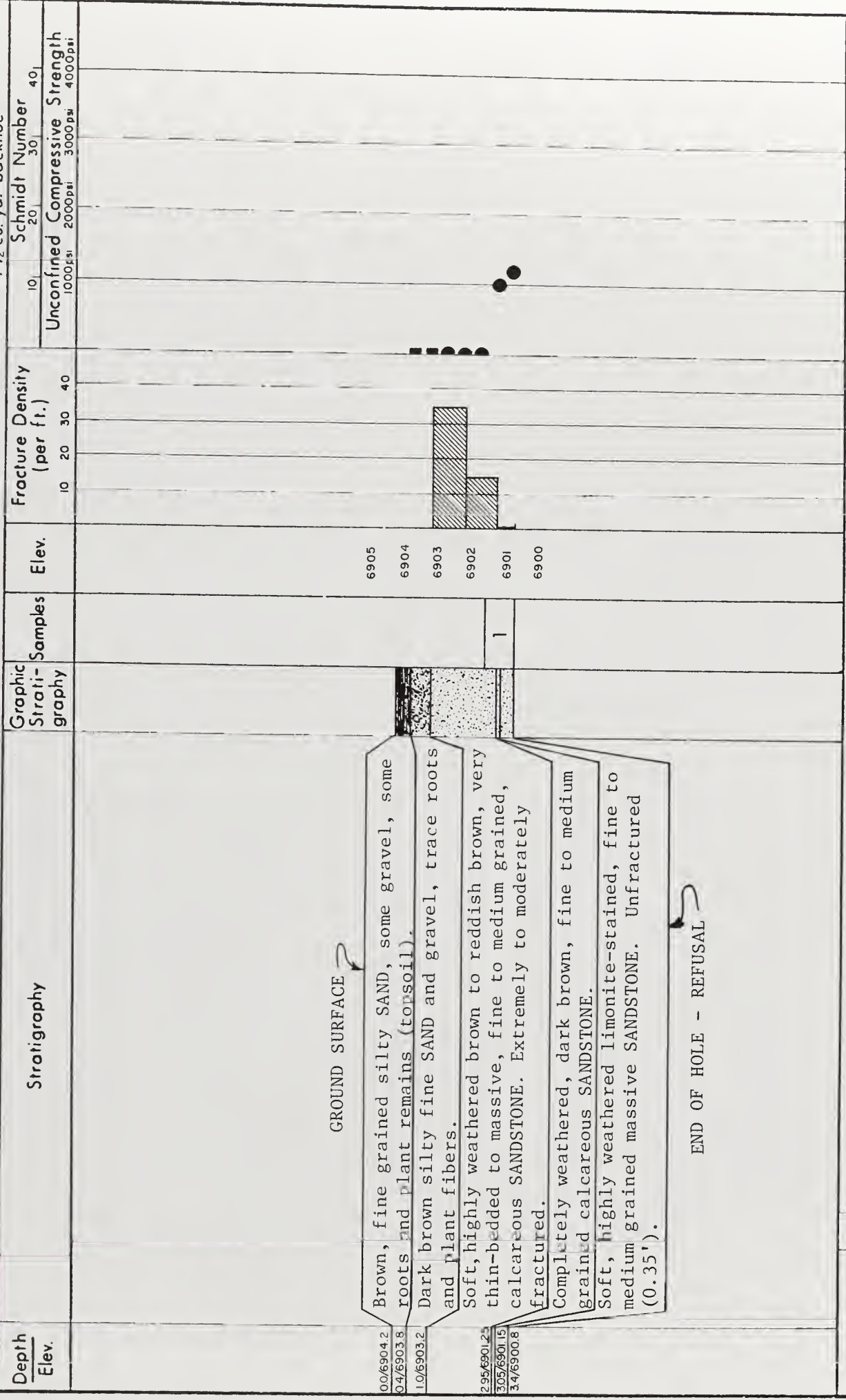
Drawn by res
Checked MF
Scale: 1 in. = 4 ft.

Golder Associates

Legend:  Schmidt No. Soil  Schmidt No. Sandstone  Schmidt No. Siltstone  UCS Sandstone  UCS Siltstone

RECORD OF TEST PIT No. 2

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 9, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

Drawn by res
Checked W/E
Scale: 1 in. = 4 ft.

Golder Associates

Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

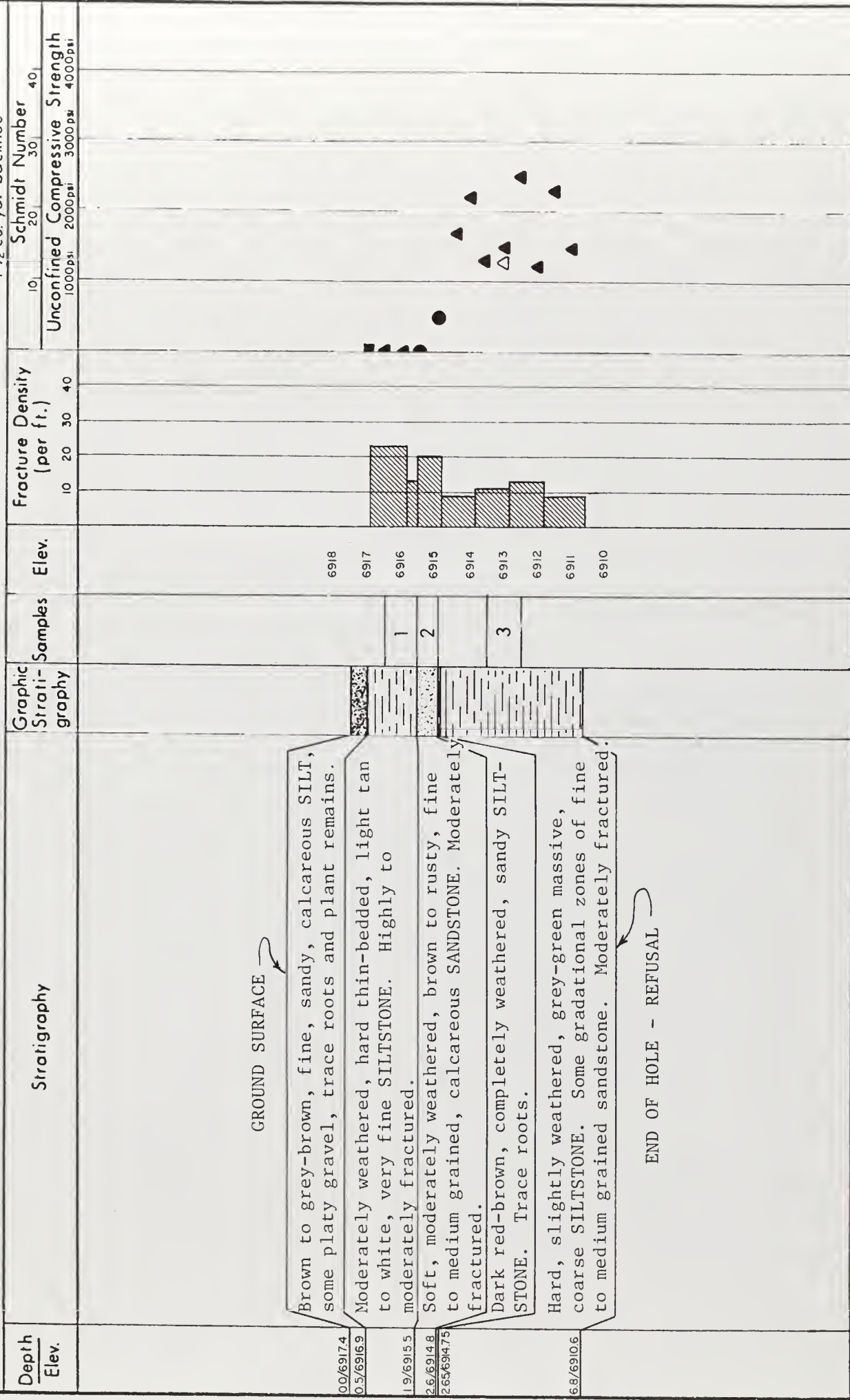
RECORD OF TEST PIT No. 3

Location: See Figure 2

Datum: Mean Sea Level

Date Completed: Oct. 9, 1975

Equipment:

Warner Swasey L-700
1 1/2 cu. yd. backhoe

REMARKS:

Drawn by res
Checked JLF
Scale: 1 in. = 4 ft.

Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

Golder Associates

RECORD OF TEST PIT No. 4

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 10, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)	Schmidt Number			Unconfined Compressive Strength
						10	20	30	
00/6883.0	GROUND SURFACE			6883					
	Brown to dark reddish brown, fine, silty SAND and fine to coarse gravel. Some lenticular coarse, angular gravel deposits. Trace roots. Thickness variable.			6882					
				6881					
35/6879.5				6880					
	Soft, highly to moderately weathered, interbedded, slightly to moderately calcareous, fine, silty SANDSTONE and coarse siltstone. Highly to moderately fractured.			6879					
				6878					
				6877					
				6876					
77/6875.3				6875					
	Soft, moderately weathered, brown to rusty, medium to coarse, massive SANDSTONE. Moderately calcareous. Moderately fractured.		1	6874					
				6873					
104/6872.6				6872					
1105/6871.95	Hard, slightly weathered, light grey brown, fine to medium grained, SANDSTONE. Moderately fractured to medium grained, SANDSTONE. Moderately fractured.		2	6871					
	Soft, highly weathered, medium to coarse grained SANDSTONE, some very hard concretionary, fresh calcareous sandstone ledges. Moderately fractured.			6870					
				6869					
				6868					
1555/6867.45	END OF HOLE			6867					

REMARKS:

Drawn by resChecked WHE

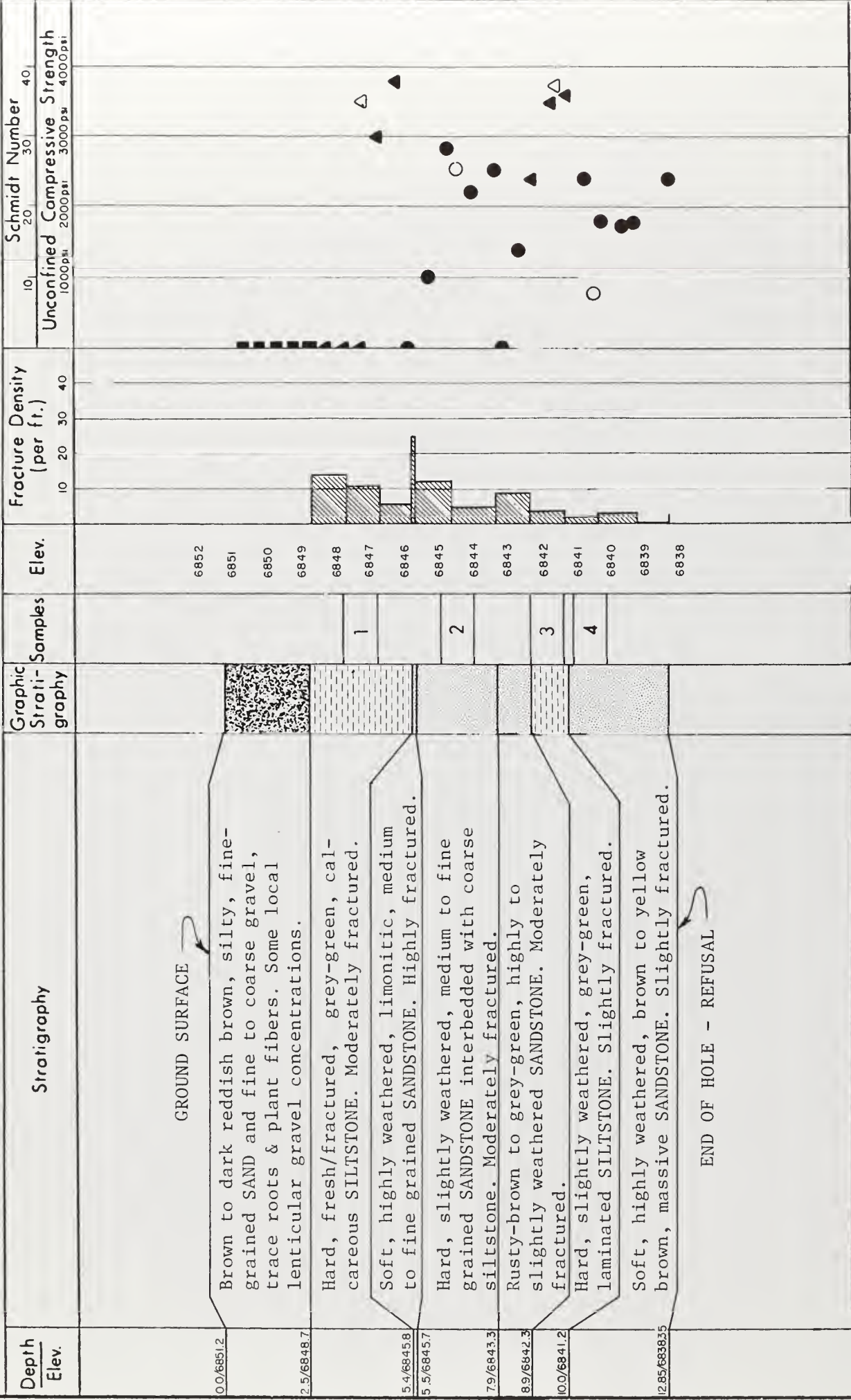
Scale: 1 in. = 4 ft

■ Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

Golder Associates

RECORD OF TEST PIT No. 5

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 10, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



Drawn by res
Checked JLH
Scale: 1 in. = 4 ft

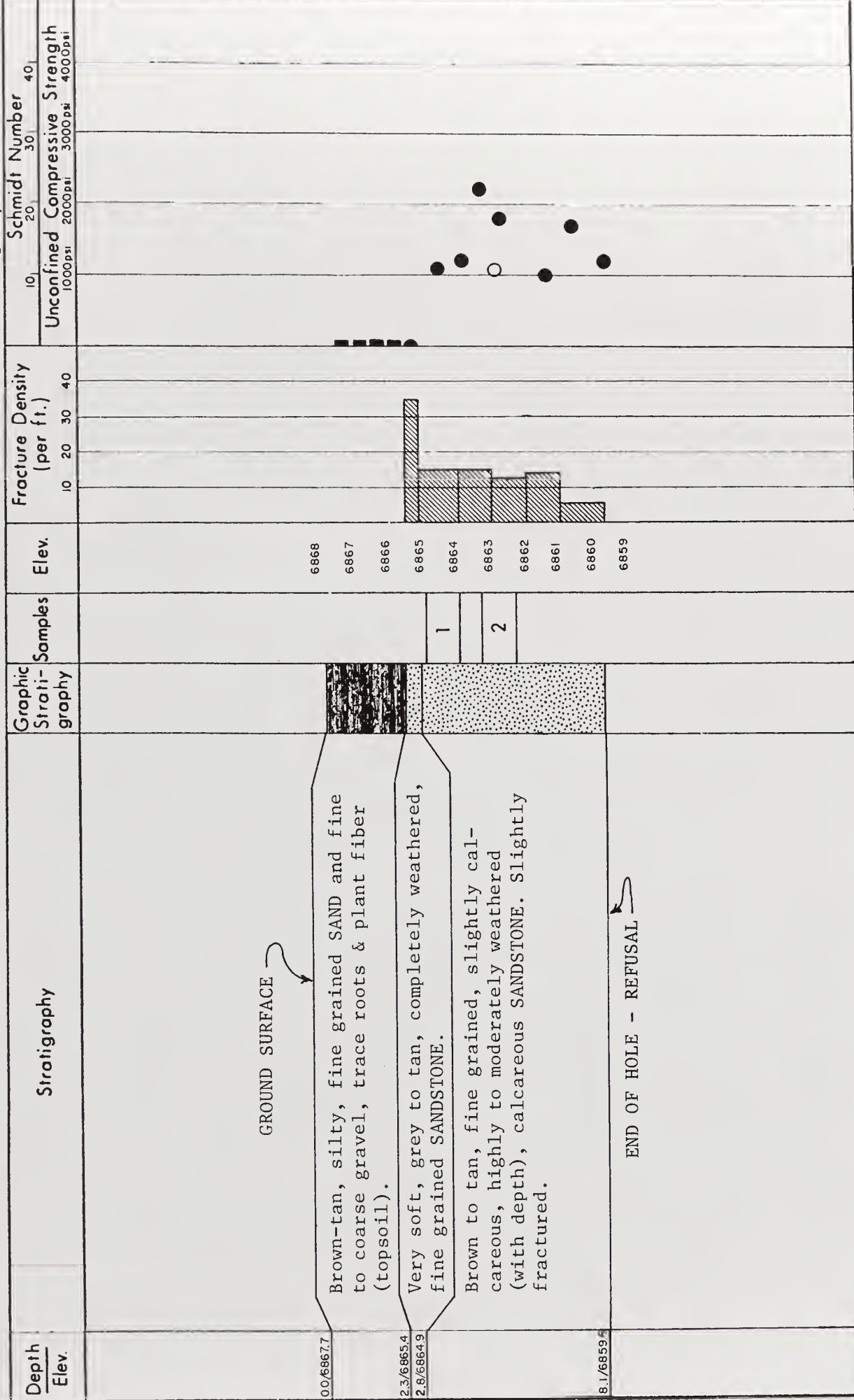
REMARKS:

Golder Associates

Legend: Schmidt No Soil Schmidt No Sandstone Schmidt No Siltstone UCS Sandstone UCS Siltstone

RECORD OF TEST PIT No. 6

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 10, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

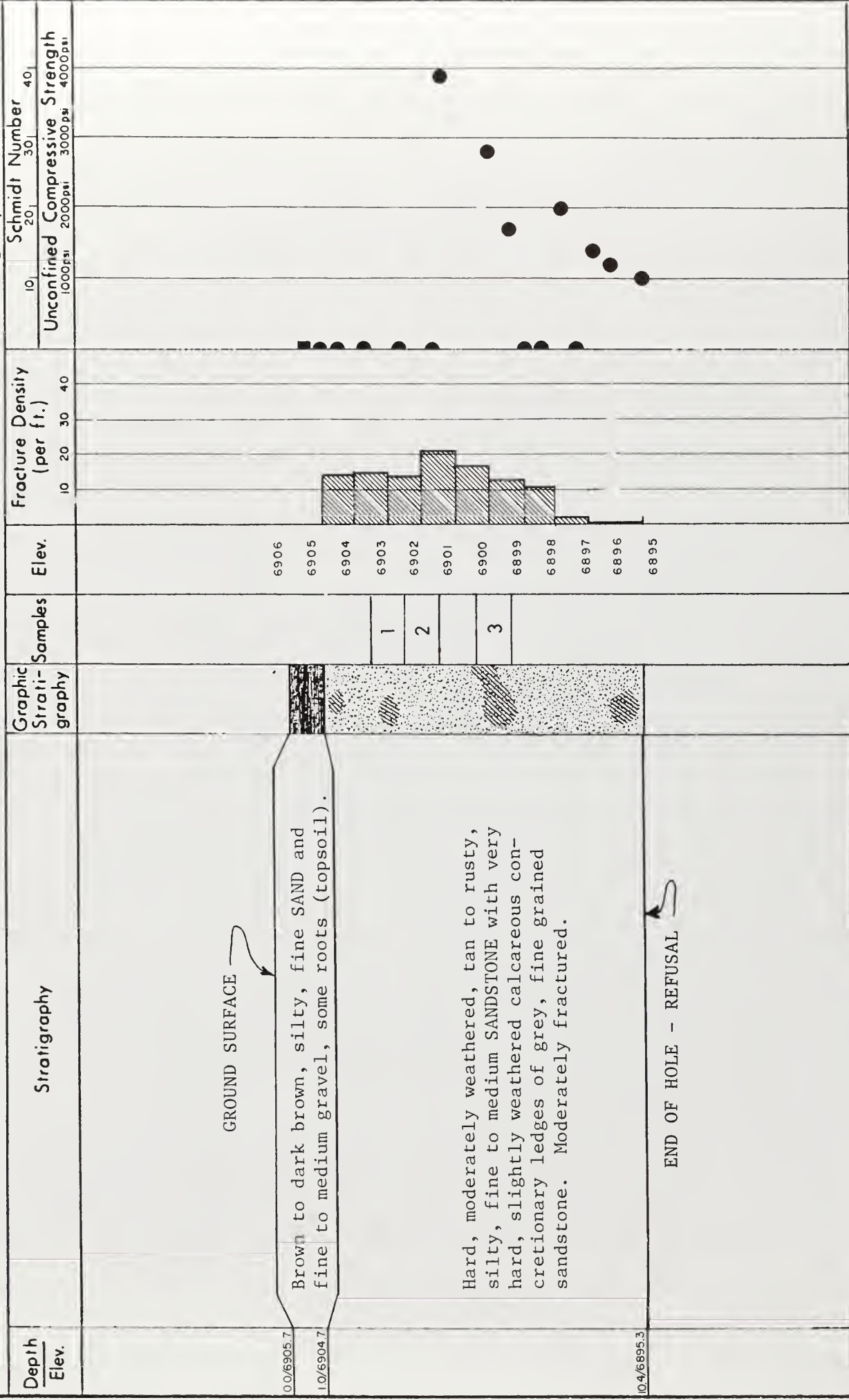
Drawn by res
 Checked ME
 Scale: 1 in. = 4 ft.

Golder Associates

☐ Schmidt No. Soil
 ☐ Schmidt No. Sandstone
 ☐ Schmidt No. Siltstone
 ☐ UCS Sandstone
 ☐ UCS Siltstone

RECORD OF TEST PIT No. 7

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 10, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



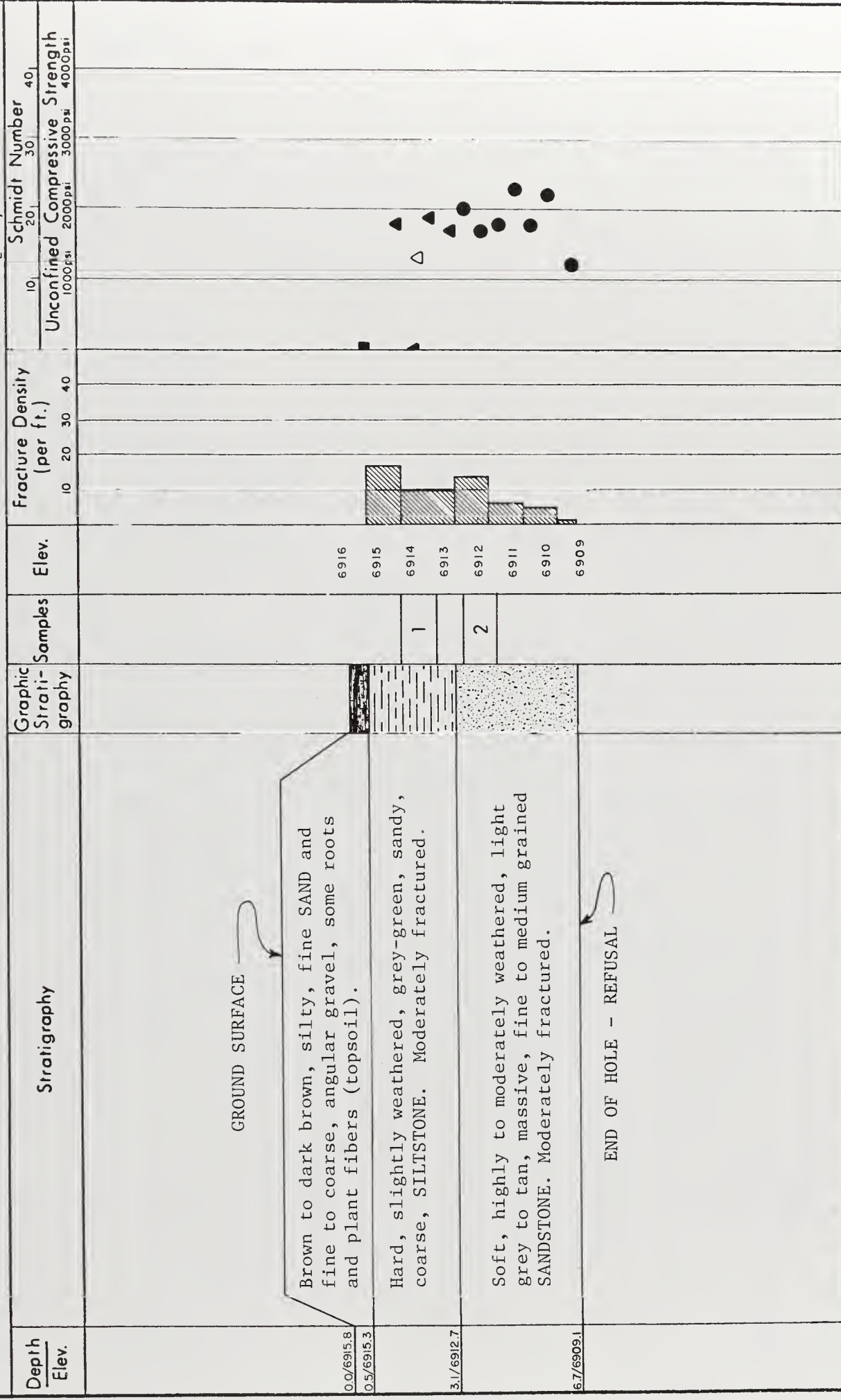
REMARKS:

Drawn by res
Checked WHE
Scale: 1 in. = 4 ft.

Golder Associates

■ Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

Location: See Figure 2	Datum: Mean Sea Level	Date Completed: Oct. 10, 1975	Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe
------------------------	-----------------------	-------------------------------	---



REMARKS:

Drawn by res
Checked WHE
Scale: 1 in. = 4 ft.

Goldier Associates

 Schmidt No. Soil
 Schmidt No. Sandstone
 Schmidt No. Siltstone
 UCS Sandstone
 UCS Siltstone

RECORD OF TEST PIT No. 9

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 13, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)	Schmidt Number		Unconfined Compressive Strength
						10	20	
								1000psi 2000psi 3000psi 4000psi
0.0/6926.9	GROUND SURFACE → Brown, calcareous, silty, fine SAND, some fine to medium gravel, trace roots & plant fibers. Gravel predominant in lower 0.2' (topsoil). Soft, highly to moderately weathered (with depth), greenish brown, slightly calcareous, fine, sandy SILTSTONE. Extremely fractured. Soft, highly weathered, dark brown SILTSTONE. Some roots in partings. Highly fractured. Moderately weathered, green-grey, fine, calcareous, silty SANDSTONE, grading downward into grey-green, coarse, massive siltstone. Slightly fractured. END OF HOLE - REFUSAL		1	6927				
				6926				
				6925				
				6924				
4.2/6922.7				6923				
5.2/6921.7				6922				
5.4/6921.5				6921				
				6920				
7.9/6919.0				6919				

REMARKS:

Drawn by res
Checked MHE
Scale: 1 in. = 4 ft.

Golder Associates

■ Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

Warner Swasey L-700
1 1/2 cu. yd. backhoe

Equipment:

Location: See Figure 2

Datum: Mean Sea Level

Date Completed: Oct. 13, 1975

Equipment:

Warner Swasey 1700
11/11/11 11/11/11

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)	Schmidt Number				Unconfined Compressive Strength
						10	20	30	40	
						1000psi	2000psi	3000psi	4000psi	
00/69243	GROUND SURFACE			6925						
	Brown to light brown, fine, calcareous SILT and sand, trace gravel. Trace roots (topsoil).			6924						
				6923						
				6922						
3.7/6920.6				6921						
			1	6920						
				6919						
			2	6918						
				6917						
				6916						
				6915						
9.5/6914.8				6914						
	END OF HOLE - REFUSAL									

</

REMARKS:

Drawn by res
Checked 711F

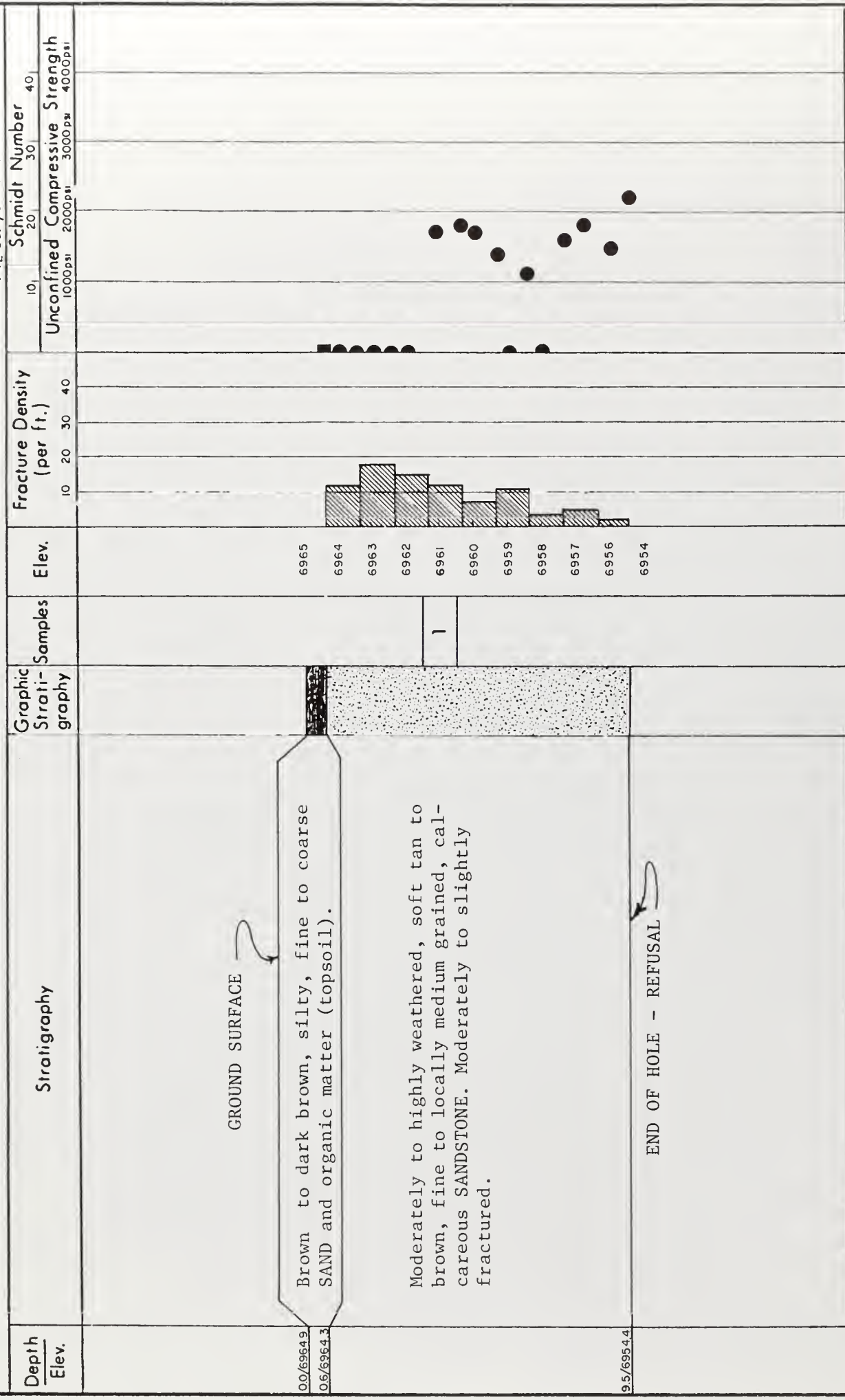
Scale: 1 in. = 4 ft.

 Schmidt No Soil
 Schmidt No Sandstone
 Schmidt No Siltstone
 UCS Sandstone
 UCS Siltstone

Golder Associates

RECORD OF TEST PIT No. 11

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 13, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

Drawn by res
Checked DHF
Scale: 1 in. = 4 ft.

Goldier Associates

Legend:  Schmidt No. Soil  Schmidt No. Sandstone  Schmidt No. Siltstone  UCS Sandstone  UCS Siltstone

RECORD OF TEST PIT No. 12

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 13, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)				Schmidt Number				Unconfined Compressive Strength						
					10	20	30	40	10	20	30	40	1000psi	2000psi	3000psi	4000psi			
	GROUND SURFACE																		
0.0/6960.1	Light brown to brown, silty, fine grained SAND, some gravel, trace roots & plant fibers (topsoil).			6961															
1.5/6958.6	Light brown to greenish, sandy SILT, inter-tongued with brown, fine, gravelly sand.			6960															
				6959															
				6958															
				6957															
				6956															
5.4/6954.7	Soft, completely weathered, green-grey, silty, calcareous, fine grained SANDSTONE.			6955															
6.5/6953.6	Hard, fresh, massive, calcareous SILTSTONE. Unfractured.			6954															
7.1/6953.0	END OF HOLE - REFUSAL		1	6953															

7860

REMARKS:

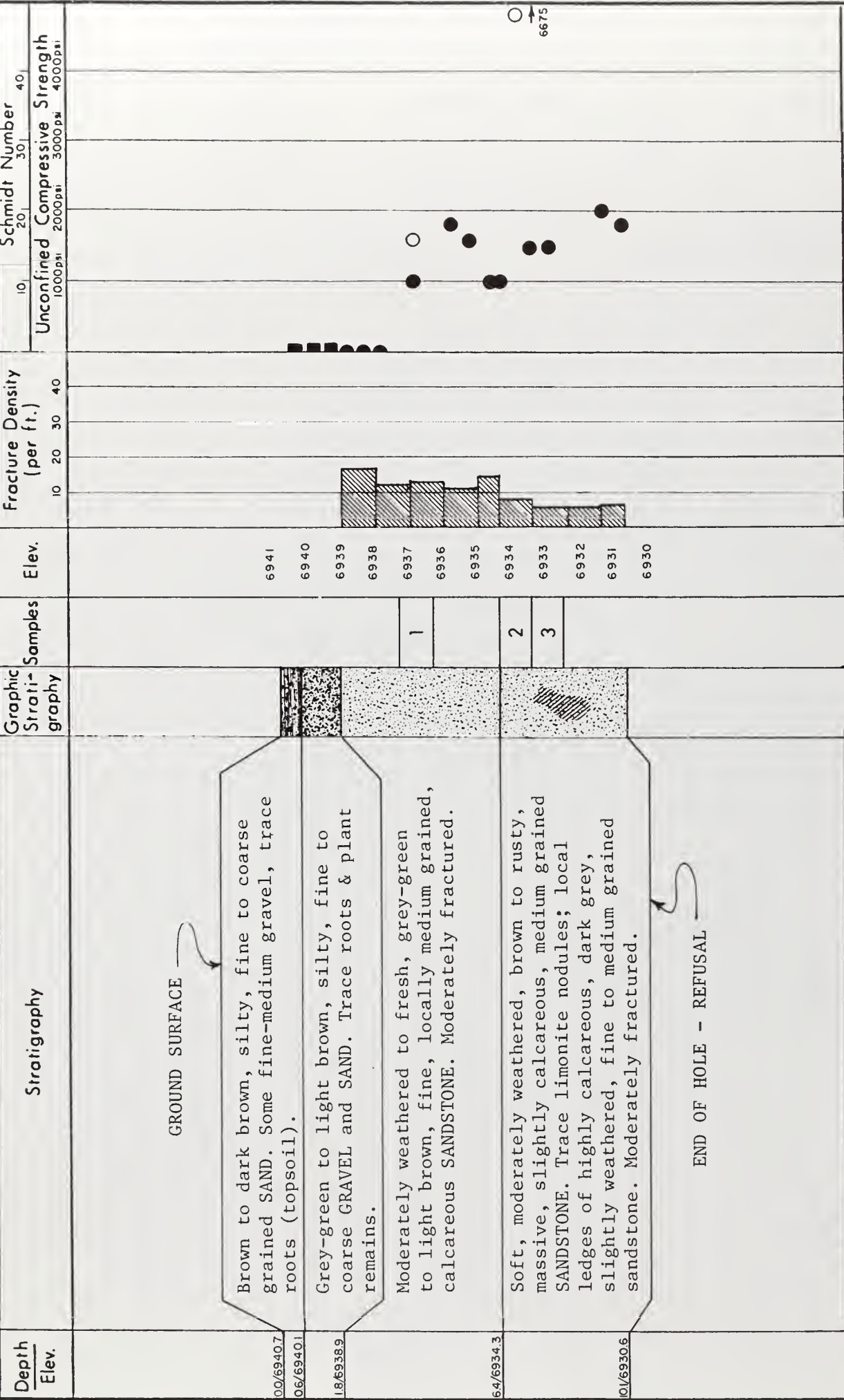
Drawn by res
 Checked THF
 Scale: 1 in. = 4 ft.

Golder Associates

☐ Schmidt No. Soil
 ☐ Schmidt No. Sandstone
 ☐ Schmidt No. Siltstone
 ☐ UCS Sandstone
 ☐ UCS Siltstone

RECORD OF TEST PIT No. 13

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 13, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

Drawn by res
Checked THF
Scale: 1 in. = 4 ft.

Legend:  Schmidt No. Soil  Schmidt No. Sandstone  Schmidt No. Siltstone  Schmidt No. Sandstone  Schmidt No. Siltstone  Schmidt No. Sandstone  Schmidt No. Siltstone

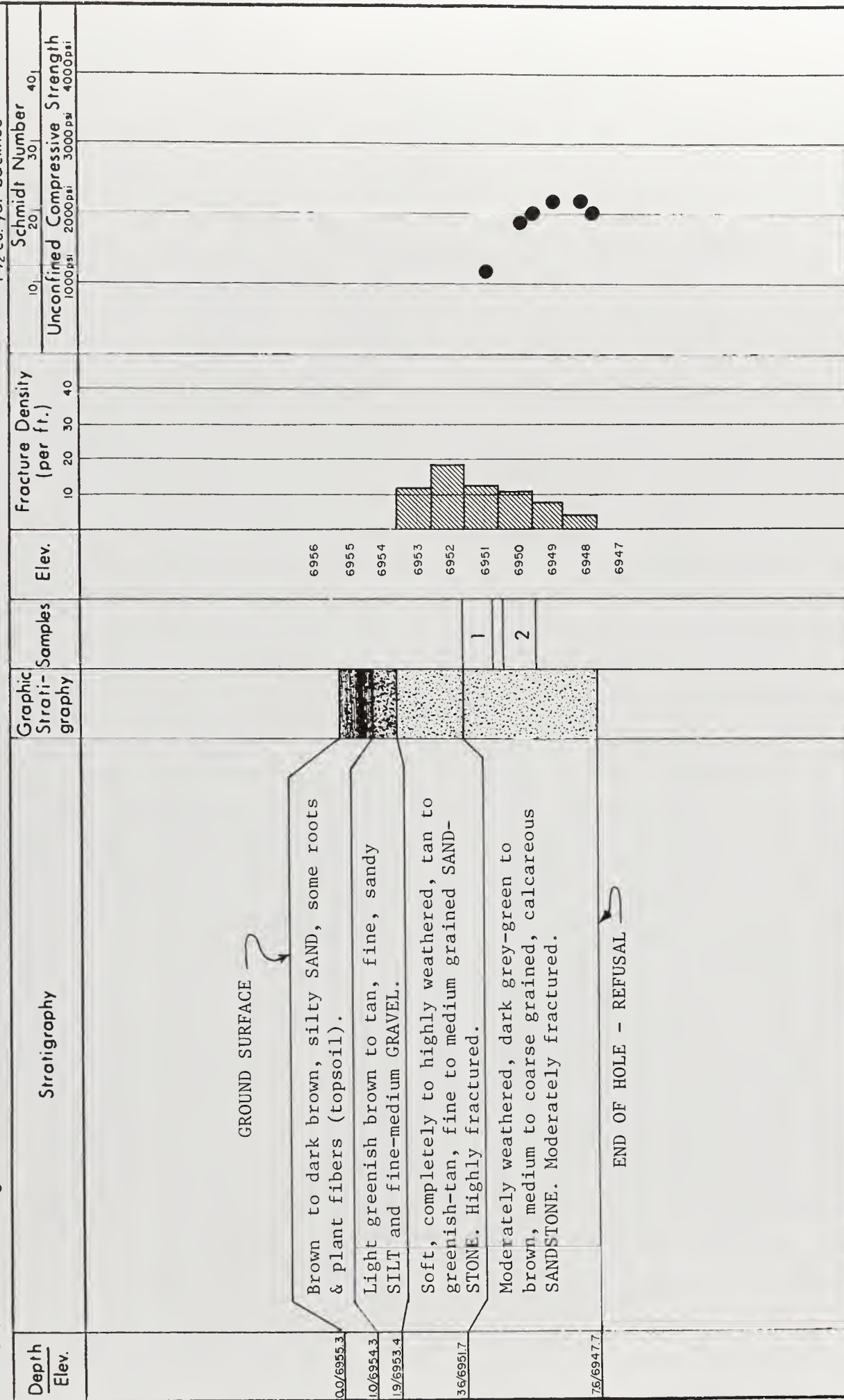
Golder Associates

RECORD OF TEST PIT No. 14

Location: See Figure 2

Datum: Mean Sea Level

Date Completed: Oct. 13, 1975

Equipment: Warner Swasey L-700
1 1/2 cu. yd. backhoe

REMARKS:

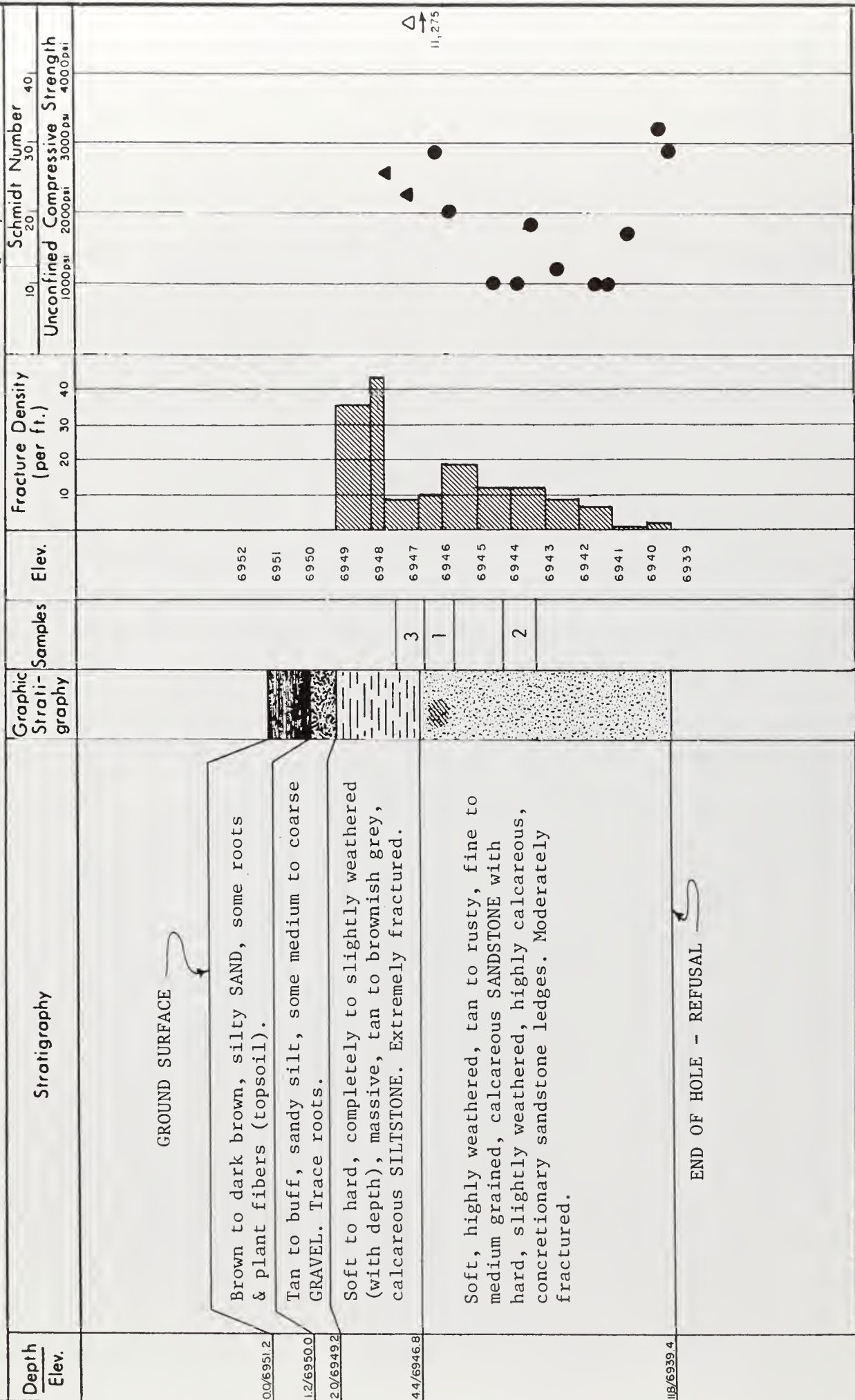
Drawn by res
Checked ME
Scale: 1 in. = 4 ft.

Golder Associates

Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

RECORD OF TEST PIT No. 15

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 13, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

Drawn by res
Checked ME
Scale: 1 in. = 4 ft

Legend: Schmidt No. Soil Schmidt No. Sandstone Schmidt No. Siltstone UCS Sandstone UCS Siltstone

Goldier Associates

RECORD OF TEST PIT No. 16 Profile 1

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 20, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)	Schmidt Number			Unconfined Compressive Strength
						10	20	30	
									1000 psi 2000 psi 3000 psi 4000 psi
	GROUND SURFACE								
00/68072	Brown to dark brown, silty SAND, some gravel, trace roots (topsoil)			6807					
14/68036				6806					
				6805					
	Brown to tan, sandy SILT, some gravel			6804					
				6803					
				6802					
				6801					
74/6799.9	Moderately weathered, dark green grey to whitish, medium grained SANDSTONE, moderately to slightly fractured			6800					
				6799					
				6798					
				6797					
11/6795.9	END OF HOLE - REFUSAL			6796					

REMARKS:

Drawn by res
Checked ME
Scale 1 in. = 4 ft.

Golder Associates

Legend: Schmidt No. Soil Schmidt No. Sandstone Schmidt No. Sillstone UCS Sandstone UCS Sillstone

Location: See Figure 2

Stratigraphy

Depth
Elev.

Brown to dark brown, silty, fine SAND, some gravel, some roots (topsoil)

Light brown, fine, sandy SILT, some gravel, trace roots

Slightly weathered to fresh, gray green SILTSTONE, moderately fractured

Moderately weathered, brown to greenish brown, medium grained, massive SANDSTONE, slightly fractured

END OF HOLE - REFUSAL

REMARKS:

Drawn by res

Checked NAF

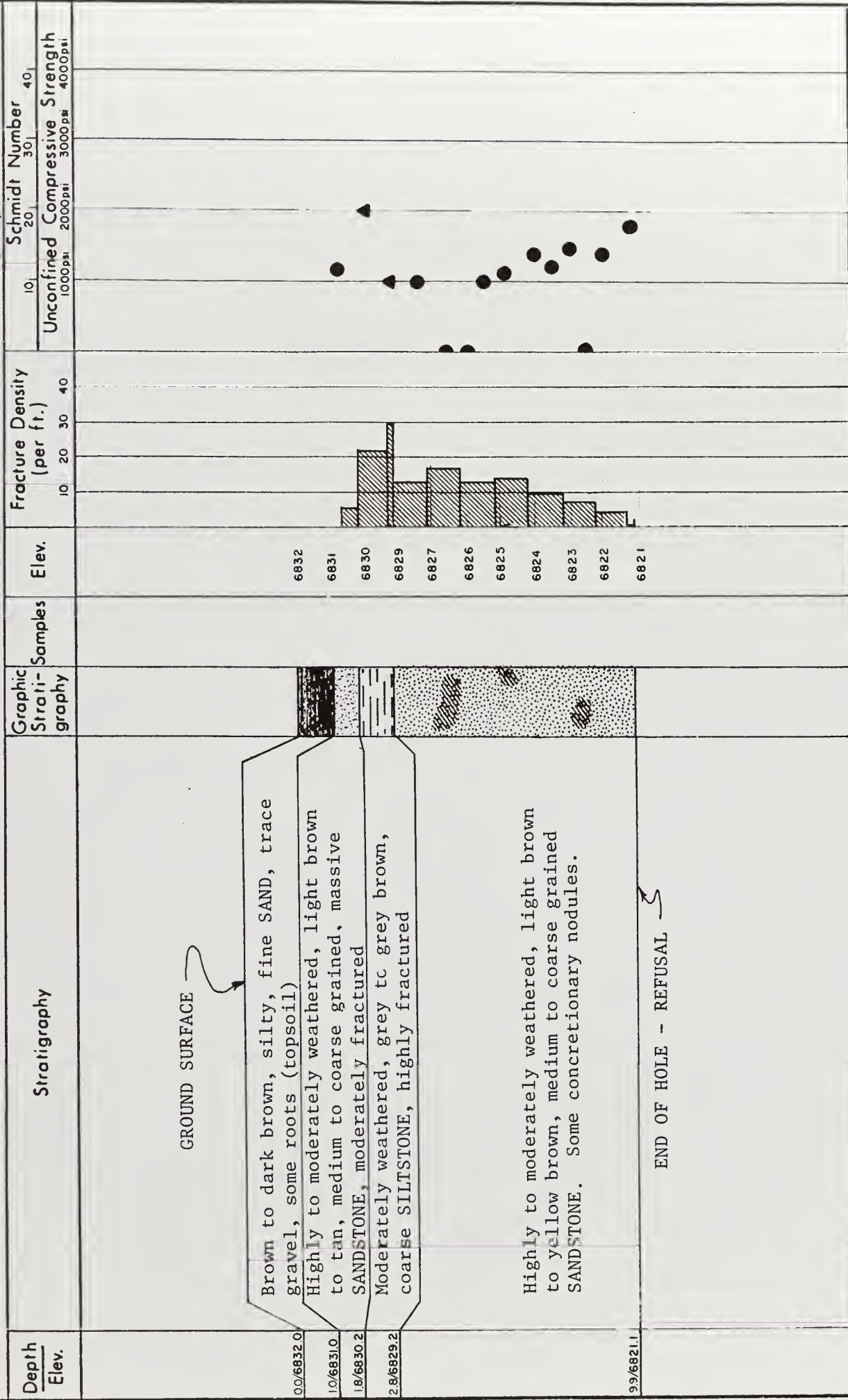
Scale: lin = 4 ft.

Goldier Associates

 Schmidt No. Soil
 Schmidt No. Sandstone
 Schmidt No. Siltstone
 UCS Sandstone
 UCS Siltstone

RECORD OF TEST PIT No. 16 Profile 3

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 20, 1975 Equipment: Warner Swasey L-700 1 1/2 cu. yd. backhoe



REMARKS:

Drawn by res
Checked ZHF
Scale: 1 in. = 4 ft.

Golder Associates

■ Schmidt No. Soil ● Schmidt No. Sandstone ▲ Schmidt No. Siltstone ○ UCS Sandstone △ UCS Siltstone

RECORD OF TEST PIT No. 16 Profile 4

Location: See Figure 2
Datum: Mean Sea Level
Date Completed: Oct. 20, 1975
Equipment: Warner Swasey L-700
1 1/2 cu. yd. backhoe

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)	Unconfined Compressive Strength 1000psi 2000psi 3000psi 4000psi	Schmidt Number 10 20 30 40
00/6850.0 04/6849.6	GROUND SURFACE Brown to dark brown, silty SAND, trace gravel, some roots (topsoil)			6850 6849			
17/6848.3	Light brown, sandy SILT, some gravel. (a) Completely weathered to fresh, whitish to light brown, sandy SILTSTONE, extremely to moderately fractured.			6848 6847			
48/6845.2	(b) Moderately weathered, brown to rusty, medium to coarse grained SANDSTONE, moderately fractured.			6846 6845			
65/6843.5 69/	(a)			6844			
72/6842.8	(b)			6843			
86/6841.4	(a)			6842			
97/6840.3	(b)			6841 6840			
	END OF HOLE - REFUSAL						

REMARKS:

Drawn by res
Checked ME
Scale: 1 in. = 4 ft.

Golder Associates

Legend: Schmidt No. Soil Schmidt No. Sandstone Schmidt No. Siltstone UCS Sandstone UCS Siltstone

RECORD OF TEST PIT No. 16 Profile 5

Location: See Figure 2 Datum: Mean Sea Level Date Completed: Oct. 20, 1975 Equipment: Warner Swasey L-700
 1 1/2 cu. yd. backhoe

Depth Elev.	Stratigraphy	Graphic Strati- graphy	Samples	Elev.	Fracture Density (per ft.)	Schmidt Number 10 20 30 40	Unconfined Compressive Strength 1000psi 2000psi 3000psi 4000psi
	GROUND SURFACE ↗						
0.0/6860.0	Brown to dark brown, silty SAND, trace gravel, some roots (topsoil)			6860			
1.3/6858.7				6859			
	Light brown to tan, sandy SILT, some gravel			6858			
				6857			
50/6855.0	Completely weathered, brown to rusty, medium to coarse grained SANDSTONE			6856			
60/6854.0				6855			
	Moderately weathered, green to greenish brown, coarse SILTSTONE, moderately to slightly fractured			6854			
				6853			
				6852			
				6851			
94/6850.5	END OF HOLE - REFUSAL ↗			6850			

REMARKS:

Drawn by res
 Checked JHF
 Scale: 1 in. = 4 ft.

Golder Associates

☐ Schmidt No. Soil ☒ Schmidt No. Sandstone ☐ Schmidt No. Siltstone ☐ UCS Sandstone ☐ UCS Siltstone

LOCATION See Figure 19

DATUM Mean Sea Level

DATE COMPLETED 11/4/75

SAMPLER HAMMER WEIGHT 140 L.B., DROP 30 IN.

BORING METHOD 4" Auger

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	"N" BLOWS/FOOT				WATER CONTENT %
			NUMBER	TYPE	BLOWS/FT.		5	10	15	20	
		SURFACE ELEVATION									
		Loose to very loose, light to dark brown layered sandy SILT and GRAVEL.	1	2"DO	6						
5			2		2	6320					
10			3		2	6315					
15			4		1	6310					
20	6306	Loose brown SILT with thin sand layers.	5		3	6305					
25			6		2	6300					
30	6298	Loose, brown to light brown uniform SAND.	7		6	6295					
35			8		4	6290					
			9		4						

REMARKS: Water level at 6.3 ft. depth Nov. 7, 1975, 10:30 AM
6.5 ft. depth Nov. 18, 1975, 10:30 AM

PROJECT NO. S75106

PROJECT C-b Tract Foundations

Golder Associates

DATE Dec. '75

BY res

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	▲ "N" BLOWS/FOOT					● WATER CONTENT %
			NUMBER	TYPE	BLOWS / FT.		5	10	15	20		
	6289.2	Color Change		2" DO								
	6287	Loose, grey to grey-brown SAND, trace silt.										
40		Loose to compact brown to light brown, then grey to blue-green layered SAND and GRAVEL.	10		12	6285				▲		
45				11		7	6280		▲			
50				12		10	6275			▲		
	6273		Color change to grey-green									
55			13		11	6270				▲		
60				14		7	6265		▲			
	6262											
65		Very loose to compact grey to blue-green SAND, with layers of sandy silt.	15		4	6260		▲				
70	6255		16		12	6255				▲		
		End of Hole										

REMARKS:

PROJECT NO. _____

Golder Associates

DATE _____

PROJECT _____

BY _____

RECORD OF BOREHOLE No. 2

Page 1 of 3

LOCATION See Figure 19

DATUM Mean Sea Level

DATE COMPLETED 11/4/75

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD 4" Auger

DEPTH'	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	"N" BLOWS/FOOT				WATER CONTENT %
			NUMBER	TYPE	BLOWS/FT.		5	10	15	20	
		SURFACE ELEVATION									
5	6319	Loose to very loose, brown to dark brown SAND with silt layers.	182	2" DC	5		▲				
			3		2	6323	▲				
10		Very loose, dark brown to light brown SILT, with layers of fine to occasionally coarse sand.	4	Push		6318	▲				
			5		1	6313	▲				
			6		3	6308	▲				
			7		2	6303	▲				
30			8		2	6298	▲				
	6294										
35			9		2	6293	▲				

REMARKS: Water Level 6.2 ft. depth, Nov. 7, 1975, 10:30 AM
7.0 ft. depth, Nov. 18, 1975, 10:30 AM

PROJECT NO. S75106

PROJECT C-b Track Foundations

Golder Associates

DATE Dec. '75

BY res

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	"N" BLOWS/FOOT					WATER CONTENT %
			NUMBER	TYPE	BLOWS / FT		5	10	15	20		
				2" DO								
40	6284	Very loose, grey-green SILT.	10		2	6288	▲					
45		Very loose, dark grey-green SILT, with layers of fine silty sand.	11		3	6283	▲					
50			12		1	6278	▲					
55	6273		13		3	6273	▲					
60		Very loose, dark grey-green silty SAND, some gravel, with layers of fine sandy silt.	14		2	6268	▲					
65			15		2	6263	▲					
			16		2		▲					
70	6258		17		5	6258	▲					

REMARKS:

PROJECT NO. _____

Golder Associates

DATE _____

PROJECT _____

BY _____

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	"N" BLOWS/FOOT					WATER CONTENT %
			NUMBER	TYPE	BLOWS / FT.		5	10	15	20		
75	6253	Loose to compact grey to grey-green GRAVEL and SAND.	18	2"DO	29	6253						29 → 4
		End of Hole										
REMARKS:												
PROJECT NO. _____						DATE _____						
PROJECT _____ Golder Associates						BY _____						

RECORD OF BOREHOLE No. 3

Page 1 of 2

LOCATION See Figure 19

DATUM Mean Sea Level

DATE COMPLETED 11/5/75

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD 4" Auger

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	"N" BLOWS/FOOT				WATER CONTENT %
			NUMBER	TYPE	BLOWS / FT.		5	10	15	20	
		SURFACE ELEVATION									
			1	2" DO	3		▲				
5		Very loose, brown to yellow-brown layered silty fine SAND.	2		1	6319	▲				
10			3		1	6314	▲				
15	6310		4		2	6309	▲				
		Very loose, brown, then grey-green SILT with layers of sand.	5		2	6304	▲				
20			6		3	6299	▲				
25			7		3	6294	▲				
30	6292	Color change to grey-green	8		1	6289	▲				
35											

REMARKS: Water Level 4.7 ft. depth, Nov. 7, 1975, 10:30 AM
5.0 ft. depth, Nov. 18, 1975, 10:30 AM

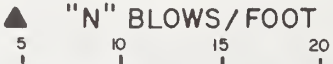
PROJECT NO. S75106

PROJECT C-b Tract Foundations

Golder Associates

DATE Dec. '75

BY res

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	 				
			NUMBER	TYPE	BLOWS / FT		WATER CONTENT %				
		Grey-green SILT with layers of sand.		2" DO							
40			9		2	6284					
45			10		2	6279					
50	6275		11		1	6274					
		Very loose, grey to grey-green layered SILT and silty fine SAND.	12		2						
55			13		4	6269					
60	6264		14		3	6264					
		End of Hole									

REMARKS:

PROJECT NO. _____

PROJECT _____

Golder Associates

DATE _____

BY _____

RECORD OF BOREHOLE No. 4

Page 1 of 3

LOCATION See Figure 19

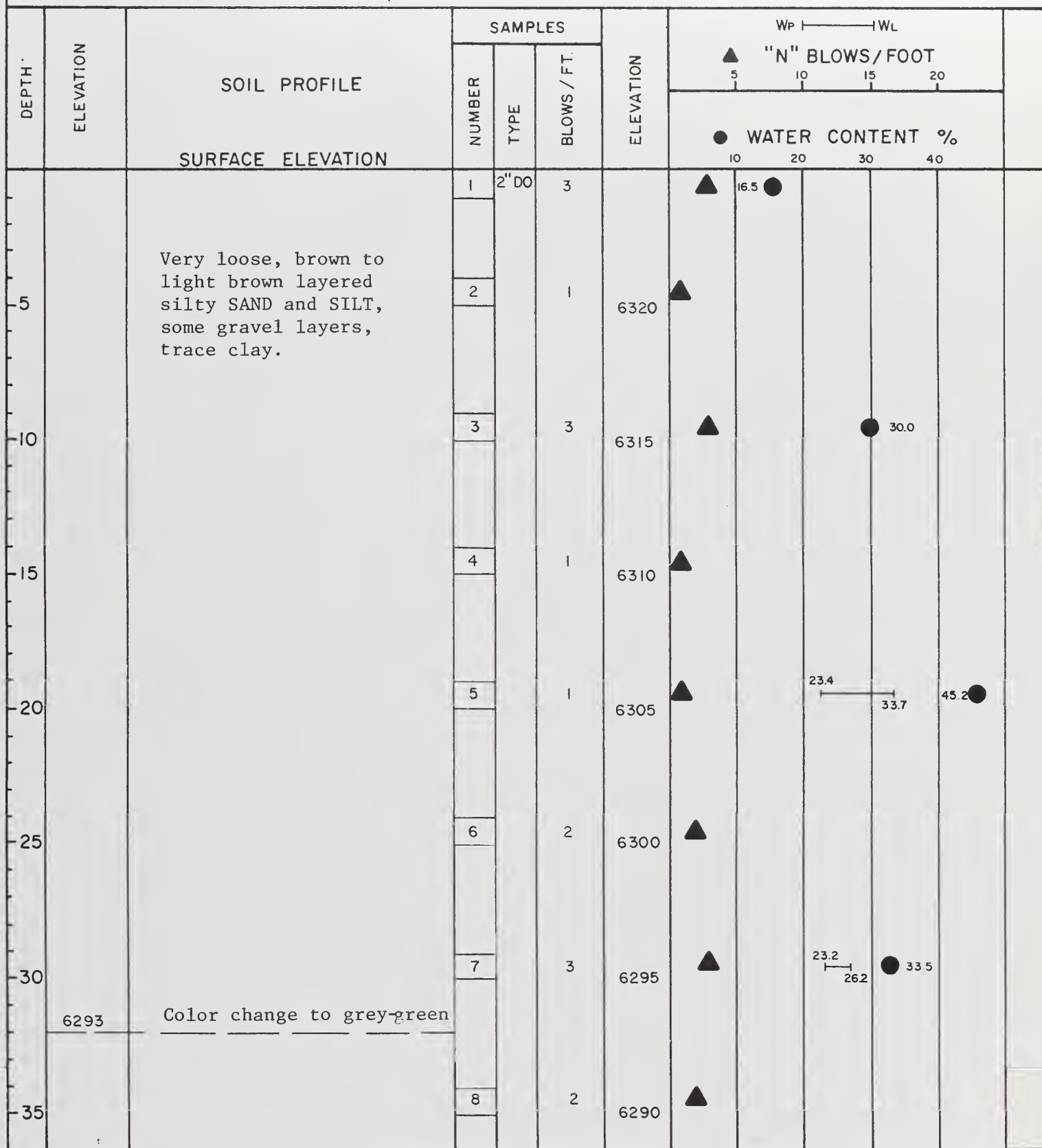
DATUM Mean Sea Level

DATE COMPLETED 11/6/75

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD

4" Auger



REMARKS: Water Level 5.2 ft. depth, Nov. 7, 1975, 10:30 AM
5.5 ft. depth, Nov. 18, 1975, 10:30 AM

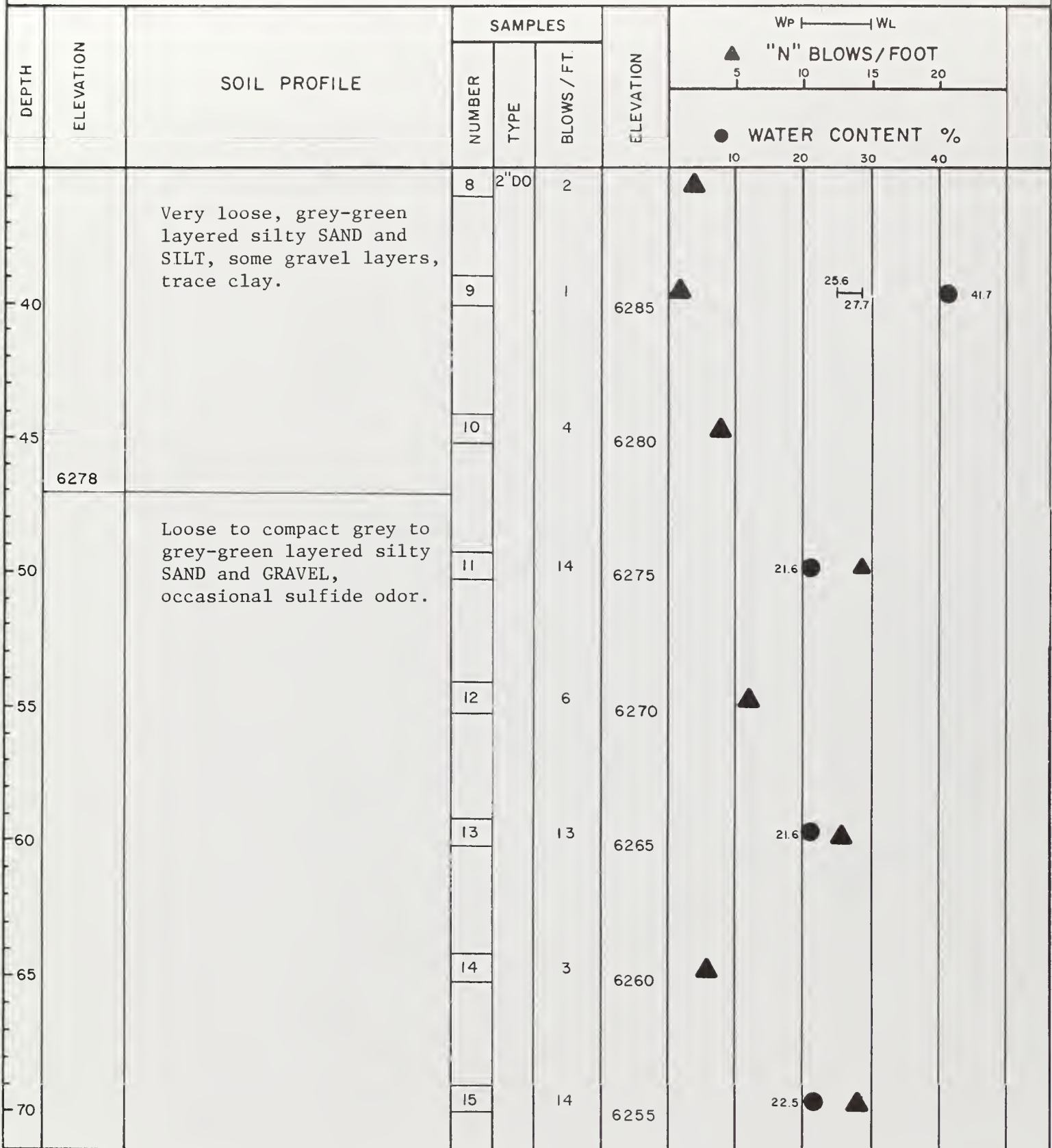
PROJECT NO. S75106

Golder Associates

DATE Dec. '75

PROJECT C-b Tract Foundations

BY res



REMARKS:

PROJECT NO. _____

Golder Associates

DATE _____

PROJECT _____

BY _____

DEPTH	ELEVATION	SOIL PROFILE	SAMPLES			ELEVATION	▲ "N" BLOWS/FOOT					
			NUMBER	TYPE	BLOWS / FT.		5 10 15 20					
							● WATER CONTENT %					
							10	20	30	40		
75	6249.5	Layered silty SAND and GRAVEL	16	2" DO	100/1"	6250					4	
	6246.5	Probably weathered thin bedded SILTSTONE.	17									
80		End of Hole			100/1"	6245			18.3 ●		4	

REMARKS:

PROJECT NO. _____

Golder Associates

DATE _____

PROJECT _____

BY _____

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APPENDIX A

Introduction

Fifteen test pits and one test trench were excavated on Tract C-b proposed plant site (Figure 2), the pits between October 9 and 13, and the trench in two days, October 17 and 20. The pits in most cases were cut to form an L-shaped excavation in order to intersect as many regionally developed fractures as possible. Excavation was accomplished with a Warner and Swasey L-700, 1½ cu. yd. backhoe. Pit depth was dependent upon various bedrock characteristics and backhoe capability.

Logging Procedures

For each pit, a single vertical section was selected as representative of the total stratigraphy of the pit. These were usually, although not necessarily, at the deepest part of the pit. Descriptions of soil and rock types, mineralization of fracture surfaces, degree of weathering, measurements of fracture density, and fracture orientations were taken at the profile strip. Photos were taken of the described zone for future reference.

For this study, fracture density was defined as the number of natural fractures, regardless of origin or orientation, intersected per foot by a vertical line traversing the pit wall. Each rock unit was measured separately for fracture density and those measured over a length of less than one foot were corrected. Although most of the rock units presented are differentiated on the basis of lithology, some were originally subdivided into two or more units of similar lithology, but different degrees of weathering or fracture density. These are presented as such under fracture density, but described as a single unit, where applicable, in the stratigraphy.

In order to derive a rough field estimate of the strength of the rocks encountered, a Schmidt Hammer was employed. This gives an estimate of strength by the rebound of a steel hammer after impact. The hammer was designed for in-situ testing of concrete, but is considered to be indicative for the rock

materials tested. Tests were conducted on all rock units encountered in the profile where practical.

Results of the Schmidt Hammer tests are generally minimum values because movement of the rocks tested often partially absorbed the hammer impact. Where hammer rebound was measureable (more than 10), the bulk of the measurements fell between 15 and 20, with a few high readings of 40 or greater.

Approximate unconfined compressive strength for Schmidt Numbers as supplied by the manufacturer are as follows:

<u>Schmidt Number</u>	<u>UCS</u>
10 - 15	>0 to 500 psi
15 - 20	500 to 1250 psi
20 - 25	1250 to 2000 psi
25 - 30	2000 to 2900 psi
30 - 35	2900 to 3900 psi
35 - 40	3900 to 5000 psi
Greater than 40	Greater than 5000 psi

Differences in equivalent strength for any Schmidt Number are introduced by variation of the angle (from horizontal) at which the hammer is held during testing. These differences were not considered in view of the variability of the original measurements. Rock samples from each test pit were collected to represent each rock unit mapped. Specimens were selected and cut to approximately 1 x 1 x 2" rectangular prisms, then subjected to unconfined compressive testing. Results of those tests are summarized in Figure 7. Stratigraphic profiles and summaries of test pit observations are presented following the figures.

Fractures of regional origin were measured for strike and dip and plotted on a Schmidt Lambert stereonet containing all measurements from test pits 1-15 (Figure 5). Fractures measured in the test trench were plotted separately (Figure 6). Qualitative descriptive terms used in describing fracturing, weathering and rock hardness are presented on the page preceding the Figures.

Summary and Conclusions

The most prominent feature observed in all of the test pits and in the test trench is the presence of a "weathered zone", averaging two feet thick, in the bedrock directly beneath the soil cover (regardless of thickness). This zone is characterized by a high degree of fracturing, and a white coating of fine calcite on fracture surfaces, setting it off from the less weathered rocks below. Frost action is evident at some locations (Figure 11b). Below this zone, the rocks are noticeably fresher, but vary in degree of weathering to the pit floors. There is no further trend to fresher rocks below the "weathered zone" observable. Data from inclined coreholes indicates alternating weathered and unweathered rock to a maximum depth of 50 feet.

Thickness of the soil cover was variable over the area sampled, with an observed range of 0.7 feet to 9.7 feet, and was generally composed of colluvial and residual detritus, with some alluvial soils observed in the pits near the bottom of Cottonwood Gulch. Topsoil was generally differentiated from the colluvial-residual underlying it by its color and organic content (Figure 11a). Thickness of topsoil averages about five inches over the sampled area, although some locations contained no differentiable topsoil.

All rocks encountered in the excavations are of the Uinta Formation. The stratigraphic units to which the rocks exposed in the test pits are assigned are those mappable subdivisions described by Amuedo and Ivey in their report dated September 19, 1975.(2) Nine of the pits were excavated in Unit 4, a series of interbedded and intertonguing sandstones and siltstones, four were in Unit 3 (not differentiated from Unit 4), one was in Unit 6 (sandstones and siltstones), and one in Unit 5 (the Scandard Gulch sandstone). The test trench, which was 570 feet long, exposed sections of Units 6, 5, and 4.

Sections exposed at the same elevations demonstrated, particularly in Unit 4, that individual layers of sandstone or siltstone could not be correlated from one pit to another. The section exposed in the test trench wall showed a definite intertonguing relationship between the lithologies, hence lateral variation within the unit.

Regardless of the unit observed, the sandstones encountered were generally fine to medium-grained, rusty brown, and moderately to highly weathered. Distinction of sandstone units on the basis of lithology alone was therefore virtually impossible. Most of the sandstones encountered in all units contained local irregular concretionary bodies of very hard, fresh, fine-grained calcareous sandstone. In Test Pit 16, these were observed in Unit 4 at or near the points where the sandstone units pinched out between siltstone beds. Observations in the other pits did not demonstrate that this relationship is necessarily consistent.

Regional fractures aggregated for all of the pits showed a major concentration with strikes trending Northwest/Southeast, and a second minor concentration trending roughly North/South. In both sets the dips averaged 60° - 65° . A third, ill defined set of fractures is oriented NE/SW with dips of 50° - 60° (Figure 5). Those measured in Test Pit 16 showed the same concentration NW/SE, but with steeper dips between 80° and 90° . The fractures in the set dipping to the South, dip in a wider range of angles than those dipping North. Comparison of fracture data collected in the pits with that from the inclined coreholes showed persistence of fracture strikes as seen on the surface at depth in the Uinta Formation. Dips are generally steeper on the surface than those indicated by corehole data (Figure 6).

Comparison of the plots of fracture density versus depth on the test pit logs shows a consistent trend to lower densities with depth. The average fracture density at refusal in all of the pits and Test Pit 16 was 5.3 fractures per foot (Figure 12a,b). Degree of weathering at refusal however, was variable. Pit floors were observed as fresh in places to highly weathered in others. Although it can be agreed that degree of weathering generally decreases with depth, it should be noted that in any given sequence, a virtually fresh siltstone may well be underlain by a highly weathered sandstone. It should be noted that moderately to highly weathered sandstones often formed the floors of the pits and are, despite the degree of weathering, considered to be competent as foundation footings.

Refusal depth in this area appears to be a function of 1) fracture density 2) bedding thickness (the more massive units comprise the floors of most of the pits) and 3) degree of weathering of the individual rock unit at refusal. Two types of refusal were noted during excavation of the

pits, and have been referred to as "soft" and "hard". Soft refusal was generally encountered in the moderately to highly weathered, massive sandstones and was characterized by grooving of the pit floor by the backhoe, rather than chipping fragments. Hard refusal occurred when the rocks could not be scored or smeared, but were shattered or chipped. This was characteristic of slightly weathered to fresh siltstones.

The plots of refusal depth and elevation versus ground surface elevation in Figure 4 illustrate the relatively constant depth over the sampled area at which refusal was encountered. The average pit depth was 9.4 feet, with extremes of 15.6 and 3.4 feet in Pits 4 and 2 respectively.

TEST PIT #1

Excavation was accomplished on October 9, 1975 at an elevation of 6888.7 ft. The legs of the pit are oriented S9°E and S69°W and are 26 and 22 feet long respectively. Maximum depth is 10.8 ft. Excavation was unhindered until about 10.2 feet were excavated in a hard, fresh siltstone, and after about five inches of penetration, backhoe refusal was encountered.

Excavation of this pit was entirely in Unit 4, described by Amuedo and Ivey as alternating fine-grained sandstones and siltstones. A thin topsoil layer (0.4 ft.) is underlain by a completely weathered layer of fine-sandy siltstone, which grades downward into moderately weathered siltstone. Weathering is complete to high to a depth of about 3.5 feet, where it becomes moderate to the last siltstone unit encountered, which is only slightly weathered.

A clear system of persistent regional fractures is evident in the undisturbed rock units. Surfaces are generally limonite stained and show no evidence of movement. Two sets are recognizable: one trending roughly North/South, and another, less pronounced, at N78°W. Spacing of the North-South set averages about nine feet, and for the East-West set, about five feet. All are closed.

Fracture density shows a corresponding decrease from extremely fractured to slight (less than 5 fractures per foot) and moderate fracturing at the bottom of the pit. Fractures are tightly closed below about 3.7 feet. Open fractures below the observable weathered zone are due to backhoe disruption. Mineralization of surfaces continues to the top of the sandstone layer.

Schmidt Hammer testing showed a general increase from the top of the first rocks encountered, remaining roughly constant through the sandstone, then increasing to about 30 at the floor of the pit.

TEST PIT #2

Excavation was completed October 9, 1975. Resistance was encountered immediately upon removal of the thin soil layer. The rocks removed were all considered to be highly weathered. Soft refusal was at 3.4 feet in soft massive sandstones. The pit was excavated in a direction N68°W for 28.9 feet, then N6°E for 19.9 ft. In the second leg, maximum depth reached was 2 feet. Surface elevation was 6904.2 ft.

Excavation was entirely in Unit 4. Rocks encountered were fine to medium-grained sandstones, ostensibly a single bed, but for a very thin persistent layer of dark reddish brown sand which is considered to be a completely weathered layer of the sandstones above and below it.

Well-developed regional fracture sets were not readily identifiable because of the shallow depth penetrated and degree of weathering of the rocks. Those which were measureable were heavily mineralized with calcite and are tightly closed except near the surface. A set at N65°E with an average dip of 60° appears with 1 to 2 foot spacing. Other fractures were measured, but did not appear to constitute recognizably persistent sets.

Fracture density showed a characteristic decrease from the surface: extremely fractured near the top of the pit to moderate fracturing in the massive sandstone near the floor. The last 0.35 foot showed no fractures, but it is likely that the rocks below the pit floor are moderately to slightly fractured.

Schmidt Hammer testing showed a marked increase in strength at 3.0 ft. and on the floor of the pit, where massive sandstone was encountered. Above this level, high degrees of weathering and fracturing rendered Schmidt Hammer tests questionable.

TEST PIT #3

Excavation was completed on October 9, 1975, at an elevation of 6917.4 ft. Progress was unhindered to a depth of about 3.0 ft. where a relatively fresh siltstone was encountered. Further excavation, although slow, was aided by the spacing and orientations of regionally developed fractures which permitted easy chipping of the rock. Hard refusal was at a maximum depth of 6.8 ft., after about 3.0 ft. of siltstone were exposed. Excavation was first in a direction of S25°W for 28 ft., then N85°W for 22.7 ft., refusal depth was essentially constant throughout the pit.

Test Pit 3 was excavated entirely in Unit 4. Siltstone was the predominant rock type penetrated, with minor thicknesses of fine-grained sandstone. A thin, persistent layer of apparently completely weathered sandstone forms the boundary between the sandstone and underlying siltstone. The first recognizable rock stratum is composed of thin beds of highly weathered, fine, sandy siltstone which have been contorted into regular garlands, probably attributable to frost action (Figure 11b).

Two major sets of regionally developed fractures are evident, one less prominent than the other. The more prominent set (11 observations) is oriented at an average N74°W, and dips 66° to the North, and individual fractures are spaced an average of 0.6 ft. apart. The other set, trending roughly North-South and dipping 65° to the East shows a spacing average of one foot for the three observations noted. A third set trending Northeast/Southwest is less distinct and more variable than the other two.

Fracture density decreases from highly fractured in the first undisturbed rock encountered, to moderately fractured at the floor of the pit.

Schmidt Hammer test results showed an increase in strength beginning at about 2.5 ft., then scattered results averaging about 20 with extremes of 16 and 23 to the bottom of the pit. The scatter is probably attributable to fracturing.

TEST PIT #4

Test pit 4 was excavated on October 10, 1975 in a direction N6°W for 29 feet, then N76°W for 52 feet. Progress was unhindered for the first 13 feet where some hard sandstone ledges were encountered. Excavation was discontinued at approximately 16 feet, where progress was slow and it was concluded that further excavation would have presented a safety hazard without extensive widening of the pit. Surface elevation was 6883.0 ft.

The entirety of Pit 4 was excavated in Unit 4. Lithologic changes were obscured by the fact that fracturing and weathering were unusually intense, as well as by backhoe disturbance. A single soil layer (topsoil not distinguishable) of variable thickness overlies a sequence of thin-bedded coarse siltstones interbedded with thicker massive sandstones. The soil is sandy, with lenticular coarse gravel deposits indicating stream deposition. An ancient stream channel is evident in the north wall of the pit, having been eroded into the sandstone and subsequently filled with the present soil cover. Thickness of the soil increased to the west to a maximum measured thickness of 7.5 feet, with inferred further thickening to the west, possibly indicative of another more deeply buried stream channel.

Fractures of regional origin were obscure because of the high degree of weathering and extensive horizontal fracturing throughout the pit. Those fractures which were measurable were at least partially disrupted during excavation, so measurements are approximate. Three sets were nevertheless recognizable from seven observations: N78°E/80°N, N11°E/65° North and South, N86°W/86°S. Spacing was not measurable.

Fracturing was generally moderate to high throughout the pit, although a trend towards lower fracture densities with depth can be seen. Even near the floor of the pit, fracture densities showed some scatter, and never fell below the moderate category except in concretionary ledges in the lower sandstones.

TEST PIT #5

Excavation of Test Pit 5 was completed on October 10, 1975, bearing N85°W for 30.4 ft., then S20°W for 27 ft. reaching a maximum depth of 16 ft. where soft refusal in sandstone was encountered. Surface elevation was 6851.2 ft. Soil was uniform in color and texture, with the exception of (1) heavy concentration of roots in the upper 2.0 in., and (2) the presence of local lenticular bodies of fine to coarse gravel, indicating stream deposition. Thickness of soil varied from 2.2 ft. to 1.0 ft. in the pit and became thicker downslope.

This pit was excavated in Unit 6, through the upper siltstone and into the middle sandstone, which formed the floor of the pit. The upper siltstone here was a sequence of alternating siltstones and thin layers of fine-grained sandstones. The sandstone layers were all more highly weathered than those containing larger percentages of silt.

Regional fracture systems were obscured, but for three measurable surfaces. Two of the three observations averaged a bearing of N88°E, and dipped steeply in opposite directions. The third was N8°W, and nearly vertical. All were mineralized with calcite.

Fracture density showed a regular decrease with depth, from moderately fractured near the top of the pit to slightly fractured on the floor. Most fractures are tightly closed except between 2.5 ft. to 4.0 ft. where horizontal fractures are filled with up to 0.5 in. of silt.

Of significance are two fractures which indicate movement of bedrock toward the gulch (Figure 13b), one of which is wedge-shaped, open at the top a maximum of 6.0 in., narrowing to closure at 10.8 ft., and striking perpendicular to the slope. It was entirely filled with white silt and sand, and indicates rotation of the western block toward Cottonwood Gulch. A second feature is an irregular opening separated from the first by a triangular block resembling a graben, although vertical movement of the block is very small. This opening is bounded on both sides by protruding blocks of rock, and resembles separation in a brickwork wall. Surfaces in the opening are rounded and mineralized with crystalline calcite.

Schmidt Hammer testing shows wide scatter, but it should be noted that the average strength of the siltstones was about 60 percent higher than that of the sandstones. Measurable Schmidt began at 4 ft. below surface.

TEST PIT #6

Excavation was accomplished on October 10, 1975, first in a direction N3°E for 32.4 ft., then N86°E for 21 ft. Surface elevation was 6867.7 ft. Progress was unhindered until 8.1 ft., where hard refusal was encountered in fine-grained sandstones. Soil was approximately 2.0 ft. thick, and graded down into completely weathered sandstone.

Excavation was through Unit 6 in the upper siltstone. The only rocks encountered were fine-grained sandstones and siltstones. The soil layer is composed of 2.3 ft. of silty sand and gravel with some roots, and a layer of completely weathered sandstone, in which original structure is evident. The last unit encountered is a fine-grained sandstone, of which 7.3 ft. were exposed. Weathering was complete to moderate with depth.

A single system of fractures was prominent, trending N62°W and dipping 73° to the South and 77° to the North, with spacing averaging 0.8 ft. All contain limonite stains and calcite dusting on surfaces exposed by excavation. A single fracture trending N15°W and dipping 53° to the West possibly represents the generally North/South system observed elsewhere.

Fracture densities showed a strong decreasing trend with depth, ranging from extreme (35 fractures per foot) in the completely weathered sandstone, to low moderate (5.5 fractures per foot) near the floor of the pit.

Schmidt Hammer test results became measurable at 3.3 ft., and but for some scatter, remained roughly constant to the bottom of the pit, with an average of approximately 16.

TEST PIT #7

Test pit 7 was excavated on October 10, 1975 in an orientation of S20°W for 32 feet. Progress was unhindered through the weathered zone to a depth of about four feet, where a ledge of extremely hard sandstone was encountered. Repeated chipping by the backhoe broke through to reveal much softer, apparently more highly weathered sandstone below. Refusal was at 10.4 feet in sandstone. A second leg was not excavated because of the difficulty encountered in the first. Surface elevation was 6905.7 ft.

This pit was excavated entirely in Unit 4, but no siltstones were observed in the section. A one foot layer of topsoil is directly underlain by highly weathered sandstone with fracture surfaces coated with fine calcite. This sandstone is the only rock unit exposed in the section, but three recognizable zones can be seen: 1) the weathered zone (0.9 feet) which appears white and is moderately fractured with open fractures; 2) a brown to rusty, soft, highly weathered, moderately fractured (closed) sandstone, within which appear 3) irregular concretionary ledges of highly indurated fresh calcareous sandstone.

Regional fracturing was poorly represented. Four were measurable: two at N47°W, 85°NE, and two at N78°W/84°N.

Fracture density remained moderate through most of the measured section, until at a depth of 8.4 feet, the fracture density dropped abruptly to slight. Many of the fractures observed in this section were probably due to backhoe disturbance. Most were tightly closed.

Schmidt Hammer testing resulted in numbers between 10 and 20, with the notable exception of the concretionary ledge at 4.6 feet, where numbers were considerably higher. Many of the low (less than 10) readings were caused by a thin layer of sand disaggregated by the backhoe, coating the pit wall surface and absorbing the hammer impact.

TEST PIT #8

Test Pit 8 was excavated on October 10, 1975, first S25°W for 33 ft., in which leg refusal was encountered at 4.4 ft. in the moderately weathered, massive sandstone. When the direction was changed to S85°W, the backhoe was able to chip through the floor along the dip of a fracture an additional 2.6 ft., bringing final refusal depth to 6.7 ft. The second leg was 19.5 ft. long. Surface elevation was 6916.8 ft.

Topsoil was 0.5 ft. thick, underlain by a slightly weathered to fresh/fractured coarse siltstone 2.6 ft. thick. Beneath the siltstone lay a highly to moderately weathered sandstone which provided refusal in the moderately weathered zone. All rocks penetrated were part of Unit 4.

Regionally developed fractures appeared frequently in this excavation and, with the exception of near the surface and where disrupted by the backhoe, were tightly closed. All were coated with fine, white calcite. Three sets appear: N25°W/73°NE, N1°E/78°N, and N79°W/71°S and 74°N. The North/South set is represented by two observations. Spacing is from 0.5 ft. to 4.0 ft.

Fracture frequency decreases regularly from moderate near the top to slight at the floor of the pit.

Schmidt Hammer testing produced results which were roughly constant over the interval tested. The average Schmidt number for both sandstone and siltstone was 18, although a wider range of numbers was evident in the sandstones.

TEST PIT #9

Test Pit 9 was excavated on October 13, 1975. Progress was unhindered until a depth of 4.2 ft. where bedrock was struck. Several subspherical concretions of sandstone were unearthed within the soil cover. Refusal was encountered at 7.9 ft. in fresh siltstone. Legs of the pit were $S55^{\circ}E$ and $S39^{\circ}W$, and 28 ft. and 24 ft. long respectively. Surface elevation was 6926.9 ft. The soil cover was 4.2 ft. thick and of homogeneous color throughout.

It was composed primarily of fine, silty sand with some siltstone gravel which proved to be unstable in a near vertical cut. A layer of highly to moderately weathered siltstone was underlain by a 0.2 ft. zone of completely weathered siltstone, with some roots. A fine sandstone constitutes the floor of the pit.

Two sets were observed in eight measurements: $N80^{\circ}W$ and $N30^{\circ}E/57^{\circ}N$, and $N62^{\circ}W/72^{\circ}N$. Spacing was approximately one fracture per foot. All were closed.

Fracture density was extreme in the weathered rock below the soil cover, but decreased to highly fractured and low moderately fractured (six per foot) near the pit floor.

Schmidt Hammer testing showed a sudden increase at 6.3 ft. and relatively constant results to the floor of the pit averaging 20. Where regional fractures were parallel to the excavation, the walls of the pit were planar and showed calcite and limonite mineralization.

TEST PIT #10

Test Pit 10 was excavated October 13, 1975, first S80°E for 27 ft., then N15°E for 26 ft. Bedrock was struck after 3.5 ft. were penetrated, and progress slowed considerably. Soft refusal was at 10.0 ft. in moderately weathered sandstone. Surface elevation was 6924.3 ft.

The soil cover was homogeneous in color and texture throughout and was nearly 4 ft. thick. No separate topsoil layer was recognized. The only other unit penetrated was a moderately weathered, fine-grained sandstone with hard concretionary ledges. Weathering was high and fractures were filled with detrital overburden in the upper 0.9 ft. of the sandstone. Moderate weathering predominated to the floor of the pit.

Regional fractures were difficult to observe due to the fact that the pit was in part excavated parallel to the joints encountered. Two observations were made: N23°W/45°N, and N60°W/83°N. Both observations appeared at the corner of the pit.

Fracture density was moderate to a depth of 8.7 ft., with slight fracturing in the last 0.8 ft. A uniform trend to decreasing fracture density with depth was observed.

Schmidt Hammer testing showed essentially constant results from 4.3 ft. down, except for high readings in the concretionary ledges. Average Schmidt number was 19.

TEST PIT #11

Test Pit 11 was excavated on October 13, 1975, first S80°E for 27 ft., then N15°E for 28 ft. The first resistance to the backhoe was encountered at about 3.5 ft., but because of favorable fracture spacing and orientation, the bedrock was easily chipped, and refusal was struck at 9.5 ft. Surface elevation was 6964.9 ft.

Two mappable units of soil and rock were penetrated in this excavation: a 0.6 ft. topsoil layer and a section of highly to moderately weathered, fine to medium grained sandstone, considered to be part of Unit 4.

Sixteen regional fractures were measured, showing two prominent sets: N76°W/71°N, and N61°E/69°S. Spacing ranges from 0.8 ft. in the first set to 2.0 ft. in the second. All fracture surfaces observed were coated with fine white calcite and minor limonite.

Fracture density showed a regular decrease with depth from moderate (between 10 and 20 fractures per foot in the upper part of the section) to slight (less than 5 fractures per foot) at the floor of the pit.

Schmidt Hammer testing indicated a sudden increase in strength below the highly weathered zone at 3.8 ft., and relatively constant readings to the bottom of the pit. Average Schmidt number was 19.

TEST PIT #12

Test Pit 12 was excavated on October 13, 1975, S81°E for 37 ft., then N23°W for 19 ft. Excavation was unhindered for 7.1 ft., the maximum depth of the pit, where a hard rock surface was encountered in virtually unweathered siltstone. Surface elevation was 6960.1 ft.

The soil cover was approximately 6.5 ft. thick, with an abrupt change to hard, fresh siltstone at 6.5 ft. The soil was divided into three recognizable units: topsoil, distinguished by its darker color and organic content (roots and plant fibers); residual/colluvial soil composed of sandy silt and intertonguing fine, gravelly sand, and a residuum composed of completely weathered siltstone.

A total of 0.6 ft. of fresh siltstone was exposed before hard refusal, and therefore no fractures other than those caused by the excavation were recognizable in the rocks.

Schmidt Hammer testing was valid only in the rock uncovered in the floor of the pit, where a maximum reading of 30 was observed. The lower number measured on the floor of the pit was probably the result of disruption and separation along a bedding surface by the backhoe, and resultant movement of the tested rocks. Both Schmidt Hammer tests were in virtually identical rock.

TEST PIT #13

Test Pit 13 was excavated on October 13, 1975, N50°E for 29 ft., then N53°W for 23 ft. Progress was unhindered for 10.1 ft., where soft refusal was encountered in sandstone. Surface elevation was 6940.7 ft.

Soil cover was approximately 4 ft. thick, with a thin topsoil layer underlain by gravel and sand, and a zone of completely weathered siltstone for a thickness of 2.2 ft. The first rock unit encountered was virtually fresh, very fine-grained sandstone, which was a gradational continuation from the completely weathered residuum above. The floor of the pit is composed of moderately weathered massive sandstones which provided soft refusal. The entire section is in Units 3 and/or 4.

A single set of regional fractures was measured in 11 observations at N76°W/83°N with an average spacing of 2.1 ft.

Fracture density was high-moderate in the first 2.0 ft. of rock, with a uniform decrease with depth to low-moderate (six fractures per foot) near the floor of the pit. A thin zone of higher fracture density was observed at a depth of about 6.0 ft.

Schmidt Hammer testing showed variable results, with a trend to increasing numbers with depth. Average Schmidt number was 14.

TEST PIT #14

Test pit 14 was excavated on October 13, 1975. Progress was unhindered to a depth of 3.6 feet, where some resistance was encountered after which excavation was slow to refusal when approximately four feet of rock were exposed. Legs of the pit were oriented N69°E and S33°W. Surface elevation was 6955.3 feet.

A one foot topsoil layer was underlain by a 0.7 foot zone of silt and gravel, the lower contact of which is gradational to completely to highly weathered fine sandstone residuum. The last four feet of rock and the floor of the pit were composed of medium to coarse-grained massive sandstone with occasional limonite pods. The entire section was considered to be part of Units 3 and/or 4.

Only five observations of regional fractures were made because the first leg of the pit was sub-parallel to the predominant set averaging N75°W/52°S and N. No other fracture sets were observed.

Fracture density shows a strong uniform decrease with depth from highly fractured in the first rocks exposed to slightly fractured near the floor of the pit.

Schmidt Hammer tests increased from 10 at 4.4 feet to 22 near the pit floor, with an average number of 19.

TEST PIT #15

Test pit 15 was excavated on October 13, 1975. Progress was unhindered for about 3.5 feet, where a hard rock surface was encountered. Because of intense and intersecting regional fracturing, the rocks were easily chipped to 11.8 feet, where soft refusal in sandstone was struck. Legs of the pit were N41°W for 31 feet and N41°E for 29 feet. Surface elevation was 6951.2 ft.

A 1.2 foot layer of topsoil was underlain by a 0.8 foot unit of sandy silt with some gravel. The first recognizable rocks encountered were completely to slightly weathered (with depth) siltstones 2.4 feet thick. An irregular ledge of hard, fresh calcareous sandstone overlies the massive, soft, moderately weathered medium-grained sandstone which comprises the floor of the pit. All rocks exposed are considered to be of Units 3 and/or 4.

Regional fractures were unusually intense. Three sets were measured in 27 observations: N73°W/67°N, N68°W/88°N, and N50°E/59°N. Spacing averaged 0.7 feet.

Fracture density was extremely high in the first foot of bedrock, with a sudden decrease at the top of the sandstone ledge, then a uniform decreasing trend to slight fracturing near the floor of the pit.

Schmidt Hammer testing showed variable results with depth. Siltstone results averaged 24, whereas the sandstones averaged 16. A marked increase in Schmidt Number was noted near the pit floor.

TEST PIT #16: SUMMARY

A trench 570 ft. long was excavated N50°W from the catchment dam and into Cottonwood Gulch. Excavation took place on October 17 and 20, 1975. The intention was to evaluate the near-surface geology beneath the proposed coarse ore storage and reclamation area. It was considered valuable to expose as much of the total stratigraphic section to be encountered in construction as possible, and to determine stratigraphic relationships which could be extrapolated to the other test pits exposing the same lithological units.

The trench was logged in five separate profiles, located so that the stratigraphy encountered in each profile would be continuous with those at lower and higher elevations. A diagrammatic cross-section was constructed for the entire trench on the basis of the data collected (Figure 9), and the lithologic units exposed correlated to those mapped by Amuedo and Ivey (2).

The excavation was cut from 6803 ft. Mean Sea Level to 6862 ft. Mean Sea Level, exposing rocks in Units 6, 5 and 4. Distances referred to are measured from the pit at its lowest elevation. Refusal depth varied considerably along the trench, with extremes of 11.7 ft. at 50 ft., to 1.0 ft. on a hard ledge encountered at 210 ft. (Figure 13a). Two such ledges were encountered in the course of the excavation. Although it was assumed that lithologic changes or differences in cementing agents were responsible for increased resistance to excavation, no specific differences could be observed in the field to account for it.

Profile 1 (20 Ft.)

Refusal depth was at 11.1 ft. below surface in massive sandstone considered to be the Middle Sandstone member of Unit 6. Soil cover was 7.1 ft., and consisted of a 1.4 ft. topsoil layer grading into a sandy silt residual-colluvial zone, the lower portion of which grades into completely weathered, in-place residual sandstone.

Fracture density decreased markedly with depth from moderate at the top of the sandstone to very slight fracturing at the floor of the pit.

Schmidt Hammer tests showed a corresponding, but slight increase with depth.

Profile 2 (100 Ft.)

A 9.7 ft. soil cover was divided into a 0.6 ft. topsoil layer underlain by a 9.1 ft. zone of sandy silt colluvium/residuum. The first bedrock encountered is a fresh/fractured siltstone, considered to be the Upper Siltstone member of Unit 6. The underlying Middle Sandstone is highly weathered and soft.

Fracture density decreased from moderate in the siltstone to slight in the sandstone. Schmidt Hammer testing showed a peak of 19 in the siltstone, with a subsequent decrease to 11 on the floor of the pit.

Profile 3 (251 Ft.)

The soil cover is much thinner here, and composed entirely of topsoil 1.0 ft. thick. The first rocks encountered were highly weathered sandstones of Unit 4, underlain by fine-grained sandstones and coarse siltstones also considered to be part of Unit 4. A thin-bedded to massive sandstone member, 7.1 ft. of which were exposed, comprises the floor of the pit, and was identified as Unit 5, the Scandard Gulch sandstone. It was marked in the top two to three feet by the presence of cross-bedding and channel features, thin friable beds of dark brown to black, fine sandstones which were lenticular in shape and could be seen to bifurcate and pinch out laterally. The sandstone became massive at the bottom of the profile.

Schmidt Hammer testing provided scattered results in the siltstones, but showed a trend to increasing strengths in the sandstone with depth. Fracture density was moderate in the first foot of rock, with decreasing densities with depth.

This section was not vertically continuous with Profile 2.

Profile 4 (402 Ft.)

Soil cover is 4.8 ft. thick and composed of topsoil for 0.4 ft., then a zone of residual sandy silt grading down into highly weathered to fresh/fractured siltstone of Unit 4. The rest of the section downward is a series of alternating sandstones and siltstones, all of which are in Unit 4. The sandstones are all more heavily weathered than the siltstones.

Fracturing is extreme in the upper portion of the rocks exposed, with a uniform decrease to very slight fracturing in the floor of the section. Schmidt Hammer results are variable, with no clearly defined trend to increase or decrease with depth.

Profile 5 (550 Ft.)

Soil cover is 5.0 ft. thick and composed of a 1.3 ft. topsoil layer underlain by 2.7 ft. of sandy silt colluvium and residuum which grades at the bottom to completely weathered sandstone residuum. The rest of the section downward consists of alternating siltstones and sandstones of Unit 4.

Fracture density was extremely high and the rocks disrupted in the first rocks encountered, but measurements in the lower portion of the section show a marked decrease to very slight at the floor. Schmidt Hammer tests were affected by the looseness of the rocks, but beginning at 6.3 ft., a variable series of results persists to the floor of the trench, where a high reading of 27 was recorded.

Summary

The most significant observation noted in the test trench was the inter-tonguing relationship of the alternating sand- and siltstones in Unit 4. This would account for the lack of correlation of individual layers from one excavation to another, and the lateral variation in bedrock encountered at any given elevation.

Nearly all of the sandstones observed contained local concretionary masses of hard, fresh, calcareous sandstone. These are clearly not confined to a particular stratigraphic level, and hence are not diagnostic of a specific unit.

A total of 100 regional fractures was measured in the trench wall, and the observations plotted on a Schmidt Lambert Equal Area Projection (Figure 6). The results are consistent with those from the other pits: a strong concentration of steeply dipping joints trending NW/SE (Figure 5). The minor North/South set observed in the other excavations is not represented here.

GEOLOGICAL SUMMARY: ROAD ALIGNMENT

The C-b Access Road Alignment, as revised and provided by Stearns-Roger on November 5, 1975, was geologically mapped for the purposes of establishing the lithologies of the bedrock to be encountered during road construction, the contact points, and a rough estimate of soil thickness variations. A 1:200 scale topographic map of the area was used as a base map, and the Amuedo and Ivey surface geologic map from the report of September 19, 1975, used for stratigraphic reference. Although the beds are generally considered to be dipping to the North by a few degrees, these dips were impossible to measure in the field except at one location where a south dip of 8° was measured on the north limb of the Hunter Creek syncline. For this reason, bedding was assumed to be horizontal within the area mapped, and contacts should not be extended beyond the points shown on Figure 13.

All of the strata encountered along the alignment are of the Eocene Uinta Formation, a series of alternating beds of siltstones and sandstones, with the exception of two small outcrops of the Black Sulfur tongue of the Green River Formation which appear at the mouth of No Name Gulch. These rocks are, however, eroded and covered with alluvium and are hence unlikely to be encountered during construction.

Areas of clearly defined alluvial and colluvial cover were mapped as such. The only such area where the boundaries of surficial deposits could be established is the alluvial fan at the mouth of No Name Gulch and its extension southward into the gulch. Alluvial/colluvial deposits are universal in the upland areas and so their detailed mapping was beyond the scope of this investigation. Instead, an attempt was made to locate areas where bedrock was exposed on the surface, and those are shown by cross hatching superimposed on the map (Figure 14).

The undifferentiated rocks designated Units 7 and 8 by Amuedo and Ivey, were observed to be separable in this area into three distinct lithological types: (1) a thin-bedded to massive sandstone, (2) a thin-bedded, generally platy series of alternating siltstones and fine sandstones, and (3) the upper, or cannonball sandstone, so named because of the presence of numerous spherical

concretions of hard, well-cemented sandstone. The upper contact of this last unit was impossible to locate precisely in the field under the soil cover. The contact shown in Figure 14 is estimated on the basis of surficial float, slope break, and scrutiny of color air photos provided by Amuedo and Ivey.

Large amounts of silicified wood were encountered in the soil overlying the cannonball sandstone in an area about 150 ft. west of the road alignment. None were observed in the rock itself, except for a log approximately 4.0 ft. long and 8 in. in diameter, protruding from a surface outcrop of the sandstone. All other observations were of small chips and fragments.

Overlying Units 7 and 8 is Unit 6, differentiated by Amuedo and Ivey into Lower and Upper siltstones, and a Middle sandstone. These lithologic distinctions were not distinguishable in this area, although rocks exposed by BLM tree chaining can be seen to change in lithology. Distinct contacts were, however, impossible to locate. The weathering characteristics of the different rocks in Unit 6 are ostensibly identical, as inferred from the lack of slope changes through this Unit.

The upper contact of Unit 6 is marked by an exposed ledge of Unit 5 (the Scandard Gulch sandstone) and break in slope in the stream channel. At this point, the sandstone is coarse-grained and conglomeratic, but grades upward to medium- to fine-grained sandstone.

Units 3 and 4 are very similar in lithology and were, hence, not differentiated in the field. Both consist of thin alternating layers of fine- to medium-grained sandstones and siltstones which weather to form gentle upland slopes. The lower boundary of Unit 4 was obscured by the soil cover and the fact that underlying Unit 5 is deeply eroded. The contact shown is therefore estimated from float and air photo observations.

Thickness of soil cover was not measured, but estimates were made based upon data from the test pits and observations in the area where the trees were chained by the BLM. Extremes of thickness are given on Figure 14 for each rock unit mapped.

Two local areas of particular interest were noted during the course of the mapping. Approximately 1700 ft. south of the second PI, and east of the road by approximately 200 ft., is an area roughly ten feet square in which active movement of soil is taking place above a small seep. Flow from the seep was enough only to keep the soil moist, but it is possible that flow rates increase in the spring, hence increasing slumping of the soil.

An area of apparent bedrock movement was observed approximately 1500 ft. south from the second PI, and directly on the alignment. The sandstones in this area are thin-bedded and covered with soil, but can be seen to dip into the hillside on the eastern bank of the gulch at an average of 26° . This block of inclined strata was observed as a thin ledge of resistant sandstone protruding from the soil cover for a distance of approximately 50 ft., at both ends of which the ledge becomes obscured by the soil cover. It is concluded that this is a block of rock which, at some time in the past, slumped into the valley and rotated along the slip surface such that the once horizontal beds now dip into the slope. No corresponding deformation was observed on the western slope of the gulch, and there is no evidence of recent movement. This phenomenon may be related to the slump features observed in Test Pit 5 (Figure 13b).

Form 1279-3
(June 1984)

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